THE
POPULAR SCIENCE
MONTHLY.

JUNE, 1902.

ON THE DEFINITION OF SOME MODERN SCIENCES.*

By Professor W. H. DALL,
SMITHSONIAN INSTITUTION.

INTRODUCTION.

IN the early days of this Society, as some of you may remember, it comprised those workers in science resident in Washington who were most eminent in varied branches of research. While in our Society, as in the firmament, one star differed from another star in glory, yet among those ready to contribute to the program or discussion, we might then count many of those reckoned as authorities in their special lines of work and in many different fields.

As the body of scientific men in government service, or local educational institutions, increased with the increasing importance of scientific method and the evolution of the sciences themselves, new bodies sprang into existence, aiming to exploit special provinces of the realm of science. To these naturally gravitated the members of the Philosophical Society chiefly concerned, and in the numerous flourishing organizations now existing in this city the original members of the parent association recognize its intellectual progeny.

With the differentiation of the avenues of communicating thought, it naturally came about that the chief papers in certain branches would be read in the society devoted to those specialties, and the programs of the Philosophical Society thus became less varied. But we have rather prided ourselves, and trust to the younger members to carry on the tradition, in still holding the doors open, so that any communica-

* Discussion before the Philosophical Society of Washington, March 15, 1902.

tion bearing on the increase or diffusion of knowledge is still as cordially welcome and as appropriately delivered before our Society as in the former time. It was frequently observed by the older members that among the benefits which they derived from our meetings none was greater than the opportunity of each to learn from the lips of a competent associate the conclusions formed in lines of research otherwise unfamiliar to the listener. Thus the mental horizon of each was broadened and the capacity for wider generalization and more philosophic views was duly enlarged.

As, by the operation of the causes already alluded to, the membership of the society has come to be devoted to fewer lines of research, it has still been possible to preserve our reputation for catholicity in science and its beneficial consequences, by calling from time to time on those eminent in particular branches, who may not be members of our body, to favor us with some account of the researches to which they are devoted, or of the present state of opinion as to the progress actually made.

To-night is one of those occasions; and I feel that I am only voicing the unuttered sentiments of all our members when I express our cordial appreciation of the courtesy our guests have shown us in their willingness to contribute to our program.

In considering the general subject of the evening, I was led to look up the definitions of science and law, as such, in the oldest available dictionaries of our language. The earliest noted is that of Phillips, in 1720, who tells us that science is 'knowledge founded upon or gained by certain clear and self-evident principles,' and Bailey, in 1737, holds it to be 'a framed system of any branch of knowledge comprehending the doctrine, reason or theory of the thing, without any immediate application of it to any uses or offices of life.' A study of other and subsequent definitions shows that the early lexicographers at least regarded science as a theoretical system divorced from practice.

Law, on the other hand, appears to have been regarded chiefly as a rule or measure imposed by some external authority on the subject of it. While the words used in defining these entities may have a modern meaning injected into them, it is practically certain that the minds which framed these definitions possessed no such comprehension of them.

For our purposes science is: exact knowledge of facts and their inter-relations, and, by an extension common to the language, the methods used in attaining this knowledge and the systematic statement of it when attained are included under the same name.

No better definition of law than that of Blackstone appears anywhere. He calls 'A rule of action.' We now amplify this definition by discriminating under the single name two classes of law, namely,

those imposed by authority human or divine; and the observed constant sequence of events which we codify as the 'Laws of Nature.'

As our possession of unclassified facts increases, the need of systematizing them becomes greater until of necessity a new science is framed to cover those categories not previously dealt with.

We hope to-night to learn something of some of the relatively new or modern sciences of which our program speaks.

The rapid development of what were a few years ago merely twigs of the tree of science into stout and fruitful branches is the most remarkable phenomenon of our times.

The majority of our grandfathers were content to declare that 'figures cannot lie,' a proverb which our fathers came to understand needed much qualification before it could be accepted. To-night we may hope to learn from a master in the science, something of the precautions by which the perversity of figures must be fenced about, in order to confine them to their useful and appropriate field.

It is not so long since eminent workers in economic questions believed it the duty of government to leave the operation of commercial forces to natural processes, the then unnamed 'Survival of the Fittest.' The bitter cry of ill-paid labor, the unreasoning fury of the strike riot, and the realization that in its essence civilization is the reversal of the processes of nature 'red in tooth and claw,' these, aided by an ever-growing consciousness of the brotherhood of man, were required to develop into a science the study of the wonderfully complex forces of economic civilization. Of this new science something will be told to us to-night.

For unnumbered centuries mankind has been slowly eliminating from the ranks of the hypernatural, phase after phase of the aspects of nature which he could come to understand. Slow indeed was the flow of grist from the mills of the goddess of wisdom unceasingly grinding. How should man account for that which was spiritual and impalpable, yet obvious, when he knew not the alphabet of that which was physical and material? Step by step must the stairway be laid on imperishable foundations before man might hope to ascend to the temple of knowledge. Thread by thread must the wires be spun and stretched from the verge of the known to the pillars of truth beyond the abyss of ignorance. What wonder if, even now, the great mass of mankind will hardly follow the investigator across the slender path of assured footing trembling in the higher air? Are not magicians, fortune tellers, mediums, all the phantasmagoria of magic and the occult still represented in our literature and life, and by hereditary transmission more or less imprinted on our instincts? The new science of psychology, still in the flush of youth, is pressing forward to lay these phantoms of the dusk and sweep the fogs away.

As for the last and most inclusive of all sciences, that which considers the interrelations which alone make civilization, science and progress possible; some of whose laws even the lowly ant and bee have unconsciously learned and applied; I must leave our guest of the evening to speak as one having authority. That man is a unit in a certain sense; that every individual carries with him determining atoms of his entire hereditary line, the unbroken continuity of which is the first condition of his existence; is a truism. That in another sense mankind is also a unit and that no member of the entire congregation can suffer or enjoy without effect upon the mass, is equally true if hard to realize. Once realized by the generality of mankind it seems conceivable that the flame of a genuine fraternity would illuminate the darker mysteries of life and labor, of good and evil, among us, as if from the refulgence of that shining city, not built with hands, of which the prophets tell.

STATISTICS.

BY THE HON. CARROLL D. WRIGHT,
DEPARTMENT OF LABOR.

GOTTFRIED ACHENWALL, who was born in 1719 and died in 1772, and was a professor of philosophy at Göttingen in 1750, is reported to have originated the modern statistical method. Undoubtedly others used it before Professor Achenwall, but it is as well to attribute the first specific use of the method in the modern sense to him as to any other.

The word 'statistics' is from the French 'statistique,' from the Greek 'statos,' meaning fixed or settled, from the stem 'sta,' to stand. Hence statistics means a method by which fixed or settled conditions can be determined. According to definition, statistics is first a collection of facts relating to a part or the whole of a country or people, or of facts relating to a class of individuals or interests and different countries, especially those facts which illustrate physical, social, moral, intellectual, political, industrial and economic condition or changes of condition, and which admit of numerical statement and arrangement in tabular or graphic form. Second, it is that department of political science which classifies, arranges and discusses statistical data.

As we understand it, one of the most essential primary objects of statistics is to secure a simple, concrete statement of a mass of facts the essence of which could not otherwise be expressed except by means of long and tedious descriptive language, and even by the use of such language no concrete and clearly-defined conclusion could be reached. There is no method of expressing certain things except through the statistical method. This is true when we understand that statistics

belongs to the historical or comparative method of study. The German historian, Schlosser, said that history is statistics ever advancing, and statistics is stationary history. Looking beneath the words of Schlosser, one must conclude that he meant that the constant accumulation of statistical data from period to period or from epoch to epoch —that is, statistics ever in motion—creates history, history being made up of the ever-advancing events of life which are shown through statistical methods, but that statistics of one epoch constitutes the permanent history thereof.

So the statistician, in the truest historical and comparative sense, writes history, but he writes it in the most crystallized form which can be adopted. He uses symbols, but with them he unlocks the facts of his own period so that they may be made plain to all students coming after him. He tells the story of our present state in such a way that when the age we live in becomes the past that story shall be found to exist in true and just proportions. The word 'statistics,' illustrating fixed and settled conditions, indicates the soundness of the German writer's thought and the true spirit in which the statistician should work.

The use of the statistical method in a scientific way is practically modern. In ancient times there were counts of the people, but no scientific use of the results that would warrant the application of the name statistics. These 'counts' were largely to ascertain military strength and divisions of geographical sections. David, you will remember, undertook to number the people. This effort on his part caused him a great deal of difficulty, and, so far as the history of the world is concerned, every man since David's time who has undertaken to number the people has met more or less opposition and had more or less trouble. All through history we read of counts or, as we say now, enumerations, but they were crude in the extreme and cannot be considered as statistical efforts.

Under our modern systems there are three kinds of statistics—I mean by 'kinds' methods which involve different systems to secure results. These are, first, statistics secured by the continuous record of official acts, as, for instance, the returns from the custom houses; those returns relating to imports and exports, immigration and other affairs are the results of a continuous record of events and are reported to a central office, tabulated and classified. School statistics, the returns of births, deaths and marriages—these come under this classification. They belong more clearly to the domain of bookkeeping, although statistical genius is essential in the classification and analysis of the entries.

The second class of statistics are those secured by actual enumeration, like census statistics, where aggregates are essential to the in-

tegrity of results. We must know the number of all the people, the total value of products and of capital, the aggregate wages paid in manufactures, and various other data where there would be little or no value unless all are included in the results. This class of statistics demands higher statistical qualifications, both in preparing for the enumeration and in the tabulation, classification and analysis of the results.

The third kind of statistics are those secured through a special investigation of certain representative facts. For instance if it is desired to learn the cost of producing iron and steel, it is not necessary, as in the previous case, to secure data for all the establishments engaged in such production. A few representative works offer ample information for determining cost of production. So, in endeavoring to ascertain the course of wages and prices, it is not essential to secure aggregates or data relating to all prices or to the wages paid to all the people employed.

The practical work of official statistical offices is divided into three parts also—first, the collection of data, which involves the preparation of schedules and instructions; second, the tabulation and the presentation of the results obtained, and, third, the analysis. No statistical table should ever be used without consulting carefully all textual treatment thereof, the accompanying notes and the analysis.

Facts may be presented in two ways—in tables, comparative and otherwise, and by the graphical method. The latter is popular and very effective in displaying proportions. The difficulty with it is that one cannot in a speech or in an article quote the diagrams, but it has a very important place in scientific statistics. The graphical method is carried to an absurd degree at times, but it nevertheless offers to a certain class of minds the very best method of determining results. In the final reflections upon statistics, however, one is drawn to the figures themselves.

With these preliminary statements, the general subject for discussion to-night brings us to the question: Is statistics a science or a method? It is not a matter of much consequence whether statistics constitutes a science or is simply a method. English writers on statistics generally consider it a method; continental writers, a science. American students often lean to the continental view. It is true that statistical research can be called a scientific method of determining facts and for studying various phenomena from which laws relating to life, production, distribution, consumption, etc., etc., can be drawn; and the method must be considered scientific, because by it the facts can be clearly stated, classified and analyzed, elements which make science in every department.

We speak of the science of botany, for one reason because all the

facts relating to botany can be classified, and so, as to other departments of human knowledge, classification or the lack of it may determine the scientific character of the knowledge. Science demands a classification of facts so rigid that all men will consent to its use and to the conclusions to which it may point.

Notwithstanding statistics is a science or a scientific method, its use is often empirical, deceptive, illusory and dishonest, and because of these things the method itself is often condemned. No one thinks, however, of condemning anæsthetics because the burglar chloroforms his victim, or the elementary features of arithmetic, the means by which all honest accounts are kept, simply because dishonest accounts are made possible by the same means. So many instances of the lying use of honest statistics meet one's observation that it is not remarkable that many make surprising denunciation of statistics and the assertion that anything can be proved by it is made to belittle the importance and value of the method.

It is true that one so disposed can, by dropping an essential element of a table, show the exact reverse of the truth, just as the foolish man said he could prove by the Bible itself there was no God, referring to the statement 'there is no God,' leaving out part of the whole statement, which is 'The fool hath said in his heart, there is no God.' So writers and speakers who have a particular economic theory to sustain will drop out of the statistical presentation of the facts the elements which work against them, using the others as the whole truth. This is seen very often in political speeches. The attempt to make comparison between the percentage of growth of population and the percentage of growth in the expenditures of the Federal Government, using no facts relative to the great increase in mechanical production and of wealth, is a vicious use of statistical data. Such showings are the results of the work of the statistical mechanic, the man who constructs statistical tables to order.

Statistics really take the place of observation. The latter is not trustworthy. Enumerations, counts, or records of continuous events are essential to establish accurate knowledge. But statistical science in this direction differs from the exact sciences. A few experiments may establish the fact that water freezes at a certain point or that the intermingling of two chemical agents will produce certain results, and the conclusion is that the same results will always be secured when the same elements are brought in contact; but the phenomena of life conditions and productions may not so easily be ascertained. Statistical work is full of fallacious details. Fallacies are found in the ordinary practice of striking averages. These things add to the disturbing influences resulting from any great enumeration, to perplexing differences among international trade accounts and to miscalculation by individual inquirers.

M. Quetelet, who was the first to use statistics in moral directions, explained the principles which ought to guide us in the matter of averages. He pointed out that an average may indicate two different things. For instance, one measures Nelson's monument ten times, and always with a slightly different result, and then adds the measurements together and divides the same by ten, the quotient, it is alleged, being an average or mean. So one may accurately measure the Duke of York's Pillar, the Parisian Obelisk and the Column Vendome, add the measurements together, divide the sum by three, and declare the quotient to be the average or mean height of those monuments. Quetelet contended, and very properly, that the results in the two instances are of such different significance as to require two separate names. He would limit the average or mean to cases represented by the first illustration—repeated measurements of one monument—and he would apply the term 'arithmetical mean' to cases represented by the second illustration—the measurement of several monuments. The repeated measurings of one monument result in a mean approximation to something actually existing, and this is an excellent definition of an average. The measurings and calculations having reference to a number of monuments result in no knowledge of anything existing; they simply and only indicate a relation among things actually existing.

This difficulty often appears in reporting average wages. Take, for instance, a works employing 20 men at $1 per day, 40 men at $2 per day, and 60 men at $3 per day. The ordinary bookkeeper in a counting room would add these rates together—$1, $2 and $3—making a total of $6 as the result of the different rates. He would divide 6 by 3, the number of rates, and declare that the average wages in his works was $2 per day. This is an arithmetical mean. The true average is to be obtained by a more elaborate calculation. Twenty men at $1 earn $20, 40 men at $2 earn $80 and 60 men at $3 earn $180 per day. Thus, 120 men earn $280 per day. Dividing $280 by 120, we have the true average, which is $2.33 instead of $2, the arithmetical mean. So also there are many fallacious calculations drawn from the use of percentages.

Some amusing incidents happen from this method. A writer recently declared that 300 per cent. of the Turks in the city of Washington were criminals. On investigation it appeared that there was one Turk in the city, and he had been convicted three times. So of the young student who took for his thesis the assertion that women in coeducational colleges more frequently married during their college course than men in the same institution. He found a college in which there were 100 men and 2 women. One of the men married one of the women. Hence he sustained his conclusion that 1 per cent. of the men married, while 50 per cent. of the women married. Thorold Rogers'

work 'Six Centuries of Work and Wages' contains several instances of this pernicious use of percentages. So, also, many are constantly using the unscientific conclusions drawn from concomitants—because one thing exists another logically exists contemporaneously.

These illustrations show the necessity of making statistics, the statistical method, thoroughly scientific in all directions, but this scientific conception of statistics does not warrant statisticians in using algebraic formula or in resorting to the calculus to secure results. The results under such methods rarely vary from those secured by the simple common-sense method of statistics; on the other hand, they disturb the reader and the common mind cannot understand them. All statistics should be simple, straightforward and clear, and any confusing element which disturbs this clearness is detrimental to the real purpose of the statistical method. While there are very many illustrations going to show the misuse of the method, nevertheless all right-minded men understand that, in economic questions especially, the comparative and historical method of study is the correct one, and the concrete, historical and comparative method is best carried on through the scientific use of statistics.

POLITICAL ECONOMY.

By ROLAND P. FALKNER,
LIBRARY OF CONGRESS.

THE problem of definitions is a perplexing one, and some of the most distinguished writers on political economy make no attempt to introduce their treatment by a definition. Marshall, for instance, tells us 'Political economy is a study of man's actions in the ordinary business of life; it inquires how he gets his income and how he uses it.' A definition is, at the best, but a guide-post whose accuracy cannot be tested until the path has been tried. Its principal service is as a preliminary line of demarkation in comparison with other things supposed to be more familiar than the field to be entered upon. One definition which has become commonplace is that political economy is the science of wealth, and if we abstain from any discussion of what constitutes a science and what constitutes wealth, it may be deemed measurably satisfactory.

After all, the phraseology of a definition is far less important than the matter which follows it, and while economists, in common with the devotees of other studies, have not been lacking in verbal controversies as to the definition of their subject, the subject matter of their discussions, apart from mere questions of emphasis, has been in the main identical. The question of definition resolves itself, therefore, into an

inquiry as to the scope of political economy and the methods which it pursues.

The division between the various fields of human knowledge is largely a matter of convenience, a sort of intellectual division of labor. This is particularly the case with those subjects which deal with the various aspects of human relations, especially political science, political economy and sociology. Human activities are so interlaced that it is comparatively easy, from whatever standpoint we begin their investigation, to extend the field of inquiry so as to embrace them all. There has been therefore, respecting these three subjects, much unprofitable controversy as to which should be deemed the dominant or master science and to which priority should be given. If, however, the study of each of these aspects of human society calls for peculiar aptitudes on the part of the investigator, it would seem that the best results should be obtained when each laborer cultivated his own patch without indulging in border controversies with his neighbors.

Political economy, the science of wealth, deals with man's relation to nature in the satisfaction of his material wants. Since nature does not shower its bounties abundantly, man's wants cannot be satisfied without human effort. Economics seeks to discover the general rules which govern man in this effort. Certain of the conditions of this activity are axiomatic and fundamental, while others are dependent upon time, place and circumstance.

Primary conditions are nature's limits and man's wants, and both have hitherto been accepted without inquiry. Of late years, however, economists have sought to measure man's wants, to determine their direction and intensity, and to thus ascertain their effects as molding forces in the economic activities which result from them. This has given us an analysis of demand which has been useful in pointing out the subjective elements in our economic activities, though it has led its adherents to trench closely upon the domain of psychology and has exposed them to the criticism that they have been digging in other men's gardens with inefficient instruments. The results of this analysis have been extremely interesting, and despite the protest of the psychologists, promise a restatement of economic theory based upon a more exact formulation of the laws of demand. Yet it can hardly be said that these views and the treatment which follows from them have become commonplaces of economic reasoning, and as it is the general consensus of opinion with which we are concerned, we may pass them over.

It was not until the economic processes became somewhat differentiated that the necessity for an explanation of them was felt. When men awoke to the idea that the affairs of every-day life were subject to rules and order, they observed that the processes involved were by no means simple. They saw men cooperating in the production of

goods, the fruits of this cooperation divided among the participants, the products themselves change hands from one person to another before they were used directly for the satisfaction of desire. In other words, they saw the economic sequence of production, exchange, distribution and consumption, and it became the object of political economy to discover the conditions and rules under which these phenomena were enacted in the daily affairs of men. As parts of one sequence they had relations one to another in which were enmeshed the relations of the human beings who conducted them. Upon what principle do the latter act?

Observation that to most men labor is irksome led to the axiom that in all economic activity men sought the maximum result with the minimum effort. This homely psychological generalization is as fundamental to the interpretation of economic phenomena as the equally homely physical generalization that nature's wants, with reference to man's desires, are limited. It has appeared in various guises, of which perhaps the most obnoxious is the concept of the economic man, who in all his doings follows the precepts of an enlightened self-interest —a being unknown to actual observation, who has merited the scorn which has been heaped upon him. Man in his economic dealings follows his self-interest according to the measure of his enlightment, but it cannot be denied that very frequently the light which is in him is darkness. The economic man is an ideal towards which, solely in their economic dealings and without reference to other activities, the men of every-day life strive. No adequate explanation of the affairs of life can be made on any other assumption than that men follow their rational interests so far as they perceive them and that foremost among them is the desire to obtain the largest result with the least expenditure of effort.

Thus understood, the economic man is the key by which the economist seeks to interpret the affairs of every-day life. It is simply the key, and not the subject matter to be interpreted. This the economist finds around him, varying at different stages of the world's progress with the growth of knowledge, the order of society and the diffusion of wealth.

These elementary considerations of the scope of political economy have briefly indicated the nature of its method. With a few simple generalizations it seeks to interpret the composite phenomena which it observes. Observation, therefore, and deduction are inextricably combined in it. If the concrete basis upon which it rests is forgotten and observation is thrown into the background, the result is a strongly deductive analysis which applies a few simple conditions to the successive phenomena of the economic sequence to be interpreted. This is the characteristic of the classical or orthodox school of political

economy, against which in recent times there has been a strong reaction to bring to honor again the factor of observation. It insists that this observation shall not be preliminary only, but that each successive phenomenon shall be tested by it. Price, for instance, is not an abstraction, but a concrete thing, which must be studied before we can have any proper theory of price, and so with all the phenomena of every-day life. The principle of observation applied to the past is the principle of historical research, and as a knowledge of the past is the best key to the understanding of the present, so those who hold this view have engaged in considerable historical researches which have given to their tendencies the name of the historical school. These economists have performed a notable service in pointing out the relativity of economic laws. They have dispelled the notion that the principles of political economy were fixed and immutable and that their activity was necessary to quicken the germ of development which was hidden in the older and more deductive economics. But it will be recognized that they introduce no new principles of investigation nor any to which, had they then been formulated, the great writers of earlier days could not have subscribed. They have enriched political economy by showing us that the phenomena to be interpreted are far richer and more complex than they appeared to the older economists, but they have not dispensed with the necessity of interpretation, for that is the life blood of the science.

PSYCHOLOGY.

By Professor E. A. PACE,
CATHOLIC UNIVERSITY OF AMERICA.

TO define *a priori* the nature and scope of a science is always difficult; and it is especially difficult during periods of transition. Speculation as to what psychology ought to be is of course interesting and important; but its value depends largely upon the frank recognition of what psychology actually is, or perhaps what the psychologies actually are. Even the statement that psychology is the 'science of mental processes,' owes much to its elasticity; for the psychologists who accept it differ as to the meaning of the terms 'mental' and 'process.' They differ more widely as to the worth of particular methods and hypotheses; and they are by no means unanimous regarding generalizations and laws.

This situation is due in part to the fact that psychology, on taking its place in the midst of the empirical sciences, found that these, by their rapid accumulation of data, had both lightened and increased its task. If the way was open to the solution of older problems, it was also beset by new problems which belonged, on one side at least, to phys-

iology and physics. How the methods and results of these sciences could be turned to profit, without any sacrifice of its own method or autonomy, was, for psychology, not easy to determine. Fortunately, with some friendly discussion regarding metes and bounds, psychology has not only held its own, but has also rendered service to its neighbors.

It has not abandoned its traditional method. For the analysis of the various states, processes, tendencies and activities which appear in the individual consciousness, introspection cannot be dispensed with. If it is supplemented, as we nowadays say, by other methods, this implies not that self-observation of a keener sort is our prerogative, but rather that, with clearer knowledge of the conditions upon which our mental life depends, we are enabled to study each process both in itself and in its manifold relations. Comparison is thus a conspicuous and even an essential feature of modern psychological methods.

Psycho-physical research, as the name indicates, seeks to determine the relations between mental processes and physical processes. Whether this determination and its quantitative results should be called measurement, is still a subject for discussion. But there can no longer be any question as to the value for psychology of experimental methods. With the aid of these it is now possible to compare accurately changes in sensation and variations in the quality and intensity of external stimuli, to observe closely the organic modifications which accompany emotion, and to fix, within reasonable limits, the time-rate of the most complex processes. In a general way, of course, it has always been known that there was some sort of connection between the psychical and the physical; what modern psychology accomplishes is the more detailed and more exact investigation of that connection. Similarly with the phenomena of association, memory, attention, inhibition and fatigue; their importance has long been recognized, but their thorough analysis is the outcome of experimental work.

A complete solution of the problems that are offered in this portion of the field would leave on our hands the larger problem as to the development of consciousness. That mind is a growth, that its behavior in any given moment is affected by its behavior in all the past moments, all psychologists admit. But there is much to be learned regarding the successive phases of this growth. By what steps does the mind advance from the earliest impressions of childhood to the complex activities of adult life? What share in the process shall be assigned respectively to heredity, to the influence of environment, to the mind's own reaction by impulse, imitation and the growing consciousness of ends to be attained? The answer to such questions involves obviously a comparison between later forms of mental life and its simpler beginnings which may lead us far into the province of biology. Certainly no theory of evolution can afford to disregard the mental factors any

more than psychology can overlook the results established by biological research.

This becomes more evident in view of the fact that both mental and bodily life may and too often does vary from the course of normal development. Those modifications which, either suddenly or gradually, reduce the mind to chaos, have in the past been studied chiefly on their practical side. They possess none the less an interest for psychology. By contrast at least they throw light on the normal activities of mind.

It should be noted, however, that in mental pathology as in psychophysics and in the study of normal development, comparison is simply a means of getting new information concerning those processes which appear in the normal individual consciousness. To render this information available and to coordinate the multitude of facts which it contains or suggests, some sort of theory is necessary; and there is no lack of theorizing in modern psychology.

Owing, perhaps, to the predominance of comparative methods, the theory of psycho-physical parallelism is just now in vogue. It is agreed, in general, that mental processes and physical processes take place simultaneously, and to this extent the one series may be said to parallel the other. But beyond this, discussion is rife and the end is not yet. If, on the more orthodox view, it is claimed that the two series are merely parallel, *i. e.*, without any causal nexus, it is urged on the other hand, especially in these latter times, that there must be interaction, mind producing effects in the organism and *vice versa*. While, again, it is maintained that the conscious processes have causal relations of their own—a specific psychical causality; it is also asserted that the causal relation exists for the physical processes only, and that mind gets its connectedness as an accompaniment of the bodily series.

The final adjustment of these claims may depend, in a measure, upon the eventual acceptance or rejection of the hypothesis, now favorably regarded, that every conscious state has for its organic basis the passage from centripetal effects in the brain to centrifugal effects, and consequently has its efferent or motor phase as well as its afferent or sensory phase. This hypothesis, however, leaves untouched the inquiry as to the precise way in which mind acts on body and body on mind. The latter problem, in fact, is essentially metaphysical. It points at once to the remoter region in which epistemology and criticism hold sway.

More than any other science, psychology finds itself obliged to canvass its results in the light of philosophy. Of late the statement has been made quite frankly that the way to psychology has its starting-point in philosophy. Be this as it may, psychology is, for the time being, at the stage of self-examination, taking an account of its titles to existence as a science. Not that it doubts of its proper object;

the whole range of experience and of scientific thought is before it. But the question is—how can this object be laid hold of? The spontaneous, unreflecting attitude of mind is confessedly beyond the reach of investigation. And if by reflection we endeavor to describe and to explain the mental life, do we not construct for our own purposes an object which is more or less artificial?

This criticism implies no skeptical tendency. It surely will not deter psychologists from their work of investigating the more subtle elementary processes of mind, its unfolding in the individual and its relations to the complex activities of its environment.

SOCIOLOGY.

BY LESTER F. WARD,
U. S. GEOLOGICAL SURVEY.

SO far as the definition of sociology is concerned, it is simply the science of society, or the science of social phenomena. All the more specific definitions that have been proposed have created more confusion than they have cleared up. What is needed in sociology is not definitions, but a clear presentation of the scientific principles underlying it. There is one such principle, failure to recognize which causes most of the difficulty in endeavoring to establish the science. This principle, however, is one that also applies to psychology, biology, and all the other sciences classed as 'complex'—to the biological sciences and the moral sciences. This principle may be formulated as follows:

In the complex sciences the quality of exactness is only perceptible in their higher generalizations.

Or, since exactness, *i. e.*, uniformity, invariableness, reliability, etc., is what constitutes scientific law, the same truth may be simplified and reduced to the following form:

Scientific laws increase in generality as the sciences to which they apply increase in complexity.

In sociology, therefore, which is the most complex of the sciences, the laws must be the most highly generalized. I shall not attempt to do more here than bring forward a few illustrations of the above propositions. It is clear that the method of sociology is essentially that of generalization, *i. e.*, of grouping phenomena and using the groups as units. Nature works by this method, for example, in chemistry, where it is believed that the higher compounds have as their units compounds of lower orders.

Social phenomena are obtrusive, ever-present, multitudinous. Their very proximity is a bar to their full comprehension. This I have called 'the illusion of the near,' and likened it to trying to see a city

or a forest while in its midst. The near is indefinite and unsymmetrical. It presents a multitude of dissimilar, heterogeneous objects. They appear to be without order. To see order in them they must be seen from a distance. Beauty is almost a synonym of order. A landscape is beautiful because distance has reduced its chaos of details into order. A mountain seen at a distance is a symmetrical object of rare beauty, but when one is climbing it the rocks and crags, the ridges and gulches, the trees and prostrate logs, the brush and briars, constitute a disordered mass to which the term beauty does not apply. It is much the same with social phenomena. They must be seen, as it were, at long range, which brings groups of facts into relief and shows their relations.

What Dr. Edward B. Tylor has called 'ethnographic parallels,' viz., the occurrence of the same or similar customs, practices, ceremonies, arts, beliefs, and even games, symbols and patterns, in peoples of nearly the same culture at widely separated regions of the globe, proves, except in a few cases of known derivation through migration, that there is a uniform law in the psychic and social development of mankind at all times and under all circumstances working the same results. The details will vary with the climate and physical conditions, but if we continue to rise in the process of generalization we shall ultimately reach a plane on which all mankind are alike.

Even in civilized races there are certain things absolutely common to all. The great primary wants are everywhere the same, and they are supplied in substantially the same way the world over. Forms of government seem greatly to differ, but all governments aim to attain the same end. Political parties are bitterly opposed, but there is much more on which all agree than on which they differ. Creeds, cults and sects multiply and seem to present the utmost heterogeneity, but there is a common basis even of belief, and on certain occasions all may and sometimes do unite in a common cause.

Not only are the common wants of men the same, but their passions are also the same, and those acts growing out of them which are regarded as destructive of the social order and are condemned by law and public opinion, are committed in the face of these restraining influences with astonishing regularity. This is not seen by the ordinary observer, and every crime or breach of order is commonly looked upon as exceptional. But when accurate statistics are brought to bear upon this class of social phenomena they prove to be quite as uniform, though not quite so frequent, as the normal operations of life.

The ordinary events of life go unnoticed, but there are certain events that are popularly regarded as extraordinary, notwithstanding the fact that the newspapers every day devote more than half their space to them. One would suppose that people would some time learn

that fires, and railroad accidents, and mine disasters, and boiler explosions, and robberies, and defalcations, and murders, and the whole list of events that make up the daily news, were normal social phenomena. Nearly every one of them has occurred nearly every day in nearly every country in the world during the lives of us all and those of our fathers and grandfathers. But this enormous mass of evidence has no effect whatever in dispelling the popular illusion that such events are extraordinary. There is nothing new in 'news' except a difference in the names. The events are always the same. All this applies equally to those larger events that make up the bulk of what is popularly understood as human history. Viewed from the standpoint of sociology, history contains nothing new. It is the continual repetition of the same thing under different names. This is what is meant by generalization. We have only to carry it far enough in order to arrive at unity. Society is a domain of law and sociology is an abstract science in the sense that it does not attend to details except as aids in arriving at the law that underlies them all.

We may call this the *sociological perspective*. It is the discovery of law in history, whether it be the history of the past or the present, and including under history social as well as political phenomena. There is nothing very new in this. It is really the oldest of all sociological conceptions. The earliest gropings after a social science consisted in a recognition of law in human affairs. The so-called precursors of sociology have been those who have perceived more or less distinctly a method or order in human events. All who have done this, however dimly, have been set down as the heralds of the new science. Such adumbrations of the idea of law in society were frequent in antiquity. They are to be found in the sayings of Socrates and the writings of Aristotle. Lucretius sparkles with them. In medieval times they were more rare, and we scarcely find them in St. Augustine, but Ibn Khaldoun, a Sarracen of Tunis, in the fourteenth century gave clear expression to this conception. His work, however, was lost sight of until recently, and Vico, who wrote at the close of the seventeenth century and beginning of the eighteenth, was long regarded as the true forerunner of Montesquieu. Still, there were many others both before and after Vico, and passages have been found reflecting this general truth in the writings of Machiavelli, Bruno, Campanella, Bacon, Hobbes, Locke, Hume, Adam Smith, Ferguson, Fontenelle, Buffon, Turgot, Condorcet, Leibnitz, Kant, Oken, etc.

The theologically inclined, when this truth was brought home to them, characterized it by the phrase 'God in history,' and saw in the order of events the divine hand guiding the acts of men toward some predestined goal. This is perhaps the most common view to-day outside of science. But science deals with phenomena. Sociology therefore

can only become a science when human events are recognized as phenomena. When we say that they are due to the *actions* of men, there lurks in the word 'actions' the ghost of the old doctrine of free will, which, in its primitive form, asserts that any one may either perform a given action or not according as he may will. From this point of view it is not supposed that any event in human history need have occurred. If the men whose actions caused it had willed otherwise it would not have occurred.

The scientific view of history is that human events are phenomena of the same general character as other natural phenomena, only more complex and difficult to study on account of the subtle psychic causes that so largely produce them. It has been seen more or less clearly by the men I have named and by many others that there must be causes, and the philosophy of history that gradually emerged from the chaos of existing history was simply an attempt to ascertain some of these causes and to show how they produced the effects. To those who make the philosophy of history coextensive with sociology this is all that sociology implies. Certainly it was the first and most essential step in the direction of establishing a science of society. The tendency at first was strong to discover in the environment the chief cause of social variation, and some authors sought to expand the term *climate* to include all this. This doctrine was of course carried too far, as shown by the saying that 'mountains make freemen while lowlands make slaves.' It was found that this was only half of the truth, that it took account only of the objective environment, while an equally potent factor is the subjective environment: *cælum non animum mutant qui trans mare currunt.* Character, however acquired, is difficult to change and must be reckoned with in any attempt to interpret human events. Thus expanded, the study of society from this point of view becomes a true science, and recently it has been given the appropriate name of *mesology.* The great influence of climate and physical conditions must be fully recognized. It reaches back into the domain of ethnology and physiology and doubtless explains the color of the skin, the character of the hair, and the general physical nature of the different races of men. The psychic effects of the environment are scarcely less important, and the qualities of courage, love of liberty, industry and thrift, ingenuity and intelligence, are all developed by contact with restraining influences adapted to stimulating them and not so severe as to check their growth.

The social effects are still more marked. We first see them in the phenomena of migration and settlement and the ways in which men adapt themselves to the conditions, resources and general character of the region they may chance to occupy. The question asked by the traditional boy in the geography class, why the large rivers all run

past the great cities, illustrates how clearly everybody sees natural law at work in society. It is the laws of society that determine the direction in which population moves. For example, in peoples at all advanced the head of navigation of rivers is usually the site of the principal towns. A short time ago, when water was more used than now as a power, there was usually combined with the advantages offered by the head of navigation (vessels being then smaller than now), the additional advantage of the fall in the stream, which is almost always greatest at the point where the piedmont plateau joins the coastal plain. As streams only reach their base level after emerging upon the coastal plain, this sudden fall almost always occurs a short distance above the head of navigation. As this is true of all the streams that drain a continent, a line may be drawn through this point on all the rivers and it will be approximately parallel to the coast. Such a line is called the 'fall line,' and it is a law of population that the first settlements of any country take place along the fall line of its rivers.

There are many laws that can be similarly illustrated, and careful observation reveals the fact that all social phenomena are the results of its laws. The one example given must suffice in the present case. But these social, or sociological, laws may themselves be grouped and generalized, and higher laws discovered. If we carry the process far enough we arrive at last at the fundamental law of everything psychic, especially of everything affected by intelligence. This is the *law of parsimony*. It has, as we shall see, its applications in biology, and its homologue in cosmology, but it was first clearly grasped by the political economists, and by many it is regarded as only an economic law. Here it is usually called the law of *greatest gain for least effort*, and is the basis of scientific economics. But it is much broader than this, and not only plays an important rôle in psychology, but becomes, in that collective psychology which constitutes so nearly the whole of sociology, the scientific corner stone of that science also.

We have seen that the quality of scientific exactness in sociology can only be clearly perceived in some of its higher generalizations, where, neglecting the smaller unities which make its phenomena so exceedingly complex, and dealing only with the large composite unities that the minor ones combine to create, we are able to handle the subject, as it were, in bulk. Here we can plainly see the relations and can be sure of their absolute uniformity and reliability. When we reach the law of parsimony we seem to have attained the maximum stage of generalization, and here we have a law as exact as any in physics or astronomy. It is, for example, perfectly safe to assume that under any and all conceivable circumstances, a sentient and rational being will always seek the greatest gain, or the maximum resultant of gain—his 'marginal' advantage.

Those who affect to be shocked by such a proposition fail to understand it in its full breadth. They think that they themselves at least are exceptions to the law, and that they do not always seek their greatest gain, and they give illustrations of actions performed that result in a loss instead of a gain. This is because they understand by gain only pecuniary gain, or only gain in temporary enjoyment or immediate satisfaction. If they could analyze their feelings they would see that they were merely sacrificing a present to a future advantage, or what they regard as a lower to what they regard as a higher satisfaction. When Henry Clay said (if he did say it) that 'every man has his price,' he may have merely stated this law in a new form. If we make the important qualification that the 'price' is not necessarily a money price, we may see that the statement contains a truth. Even in the lobby, which he probably had in mind, it is well known that downright bribery is very rarely resorted to. It is among the least effective of the lobbyist's methods. There are other far more successful as well as less expensive ways of gaining a legislator's vote. Passes on railroads and other favors of that kind are much more common, but even these are relatively coarse and transparent, and the great vested interests of a country know how to accomplish their ends by much more subtle means. It is only necessary to put those whom they desire to influence under some form of obligation, and this is usually easy of accomplishment. Among the most effective means to this end are social amenities and the establishment in apparently the most disinterested ways of a friendly *entente,* which appeals to the sense of honor and makes any man ashamed to act contrary to the known wishes of a friend. Under such imperative influences as these constituencies are easily forgotten.

But this is by no means the whole meaning of the law. It deals solely with motives, and worthy motives are as effective as unworthy ones. It is based, it is true, on interest, but interest is not always bad. It is much more frequently good. It was necessarily good, at least for the individual, in the beginning, since it had the mission to impel life- and race-preserving activities. Interest may be perverted, but this is the exception. Men feel an interest in doing good, and moral interest is as real as any other. Ratzenhofer shows that men have been profoundly moved by what he calls 'transcendental interests,' which he defines as a reaching out after the infinite, and to this he attributes the great religious movements of society. If therefore we take into account all these different kinds of interest, physical, racial, moral, social and transcendental, it becomes clear that all action is based on supposed gain of one or other of these orders.

Still, the world has never reached a stage where the physical and temporary interests have not been paramount, and it is these upon

which the economists have established their science. Self-preservation has always been the first law of nature, and that which best insures this is the greatest gain. So unerring is this law that it is easy to create a class of paupers or mendicants by simply letting it be known that food or alms will be given to those who ask. All considerations of pride or self-respect will give way to the imperious law of the greatest gain for the least effort. All ideas of justice which would prompt the giving of an equivalent vanish before it, and men will take what is proffered without thought of a return or sense of gratitude. In this respect men are like animals. In fact, this is precisely the principle that underlies the domestication of animals and the taming of wild beasts. So soon as the creature learns that it will not be injured or molested and that its wants will be supplied, it submits to the will of man and becomes a —parasite. Parasitism, indeed, throughout the organic world is only an application of the law of parsimony. Pauperism produced in the manner described is social parasitism. But parasitism always results in degeneracy, and pauperism, engendered in society by well-meaning persons ignorant of the law of parsimony, is social parasitic degeneracy.

While, therefore, in view of the number and variety of causes that combine to determine any single act, no law can be laid down as to how any individual will act under a given set of circumstances, we have a law which determines with absolute certainty how all men act under all circumstances. If there is any apparent exception to this law we may be sure that some element has been overlooked in the calculation. Just as, in the case of a heavenly body which is observed to move in a manner at variance with the established laws of gravitation and planetary motion, the astronomer does not doubt the universality of those laws, but attributes the phenomena to some undiscovered body in space of the proper size and in the proper position to cause the perturbation, and proceeds to search for that body; so in human society, if there are events that seem at variance with the fundamental sociological law of parsimony, the sociologist may safely trust the law and proceed to discover the cause of the social perturbation.

THE COMMERCIAL VALUE OF HUMAN LIFE.

By MARSHALL O. LEIGHTON.

ENLIGHTENED society readily grants that the lives of its members constitute its most treasured resource. Legislative authority has reserved its severest penalties for those who plot against and destroy its subjects. Along with the advancement of civilization has come a higher and higher appreciation of the inalienable right of the human organism to live its allotted time, and the most benign forms of government in the present day assume that its first duty is the preservation of the life and the comfort of its units.

Pagan history reveals a frightful waste of the resource vested in human life, and early Christian times are marked by only a slight improvement. Wanton destruction continued to be common even to a later date, and is at the present time excused under well-known and unusual circumstances. Yet the tendency has been and will ever be to preserve more and more securely bodily existence of mankind.

There are two radically distinct measures of human life. The one is purely humanitarian and considers only the divinity of man. Under such an estimate, the life of an individual must be priceless, and cannot be approximately valued in terms employed in monetary denomination. The other seeks to eliminate all sentimental considerations, and deals with the individual upon the basis of his value to the community as a productive agent, like a horse, locomotive or cotton gin. The second basis of measurement is an unpopular one, and has received so little attention that it is regarded as undeterminable by the general public. The majority of the computations set forth in the few paragraphs now available can be regarded as little more than wild, disingenious guesses.

What, then, determines the value of human life? As eminent an authority as Rochard has stated that it is the sum "that the individual has cost his family, the community or the state, for his living, development and education. It is the loan which the individual has made from the social capital in order to reach the age when he can restore it by his labor." It is hardly probable, however, that this statement will receive permanent acceptance by a thoughtful man. A little reflection will show that it reverts to the generally discredited and socialistic theory that values are determined by cost. Under such a valuation, the resource vested in an individual grows from birth, not with his increasing powers of production and the greater certainty of

his attaining the age of self-support and becoming useful, but by reason of the fact that his maintenance is costing more and more. It would mean that the individual is most valuable at the moment before he becomes self-sustaining, and thereafter loses value until he has paid back to society the cost of his maintenance during dependent years. The time arrives when the account is balanced, and he is of no value whatsoever, even though he might be at the prime of his productive powers. On the other hand, the generally accepted meaning of value has little relation to the cost of production; it depends upon final utility. The value of a commodity depends upon its use, or its productive ability in a community, and, as we are dealing with life as a commodity, in truth, an article, these well-established economic principles must apply, even as truly as in the case of commercial products, in the market of New York. The more logical view, therefore, must be that the commercial value of a life must be measured by its general usefulness, its power of production, and the monetary returns which it makes to society.

Numerous suits for damages, in courts of law, for the wrongful deaths of individuals constitute the commonest, the most fruitful and almost the only trustworthy references available in which life values are dealt with. It has been necessary for judicial authority to consider the question to a minute degree, and if the basis of computation is applicable to the conditions found in the general social universe, it ought to provide a trustworthy source of information upon the subject.

It will be seen at once that in suits at law for compensation for death, the loss is computed from the standpoint of the surviving relatives who bring the suit; a widow prays for compensation for the loss of her means of support; or a bereaved family petitions for damages occasioned by the loss of services of a mother. The question therefore to be determined is: Does the loss to the surviving relatives represent, in any degree, the loss to society? Let us examine into the conditions governing judicial procedure in cases of this kind.

The principle generally adhered to in estimates of life values is well defined by the English court procedure, and this has been followed in spirit if not in letter by the majority of the states of our union. It is, in effect, as follows: "The jury may give such damages as they shall deem a fair and just compensation with reference to the pecuniary injury resulting from such death." In nearly every state, therefore, pecuniary loss is made the basis of damages, and exemplary or punitive damages are not permitted. This means that the damages allowed in such cases represent what are believed by such courts to be actual loss, without any suspicion of punishment for the party responsible for the destruction. Such punishment assumes a charge for premeditation or criminal negligence, and is dealt with by other methods than by civil

suit. The principle surely conforms to the basis of computation applicable to the loss to society at large.

Damages cannot be given as a solatium. It is assumed that the bereavement of a party can not be soothed by an application of the coin of the realm, and the higher courts scrutinize the work of juries in order to eliminate the results of passion upon the part of the members thereof. Sympathy for the destitute orphan can have no part in the award of damages. This principle, also, conforms to the requirements in estimating the loss to society.

Nothing can be allowed for the injury to the deceased nor for physical nor mental suffering. Again appears a conformation to the conditions demanded by the social state. The loss of a mill operative in the Commonwealth of Massachusetts is indirectly felt by the inhabitants of the State of Delaware, yet such loss is not greater by reason of the physical disfigurement of said operative nor the mental sufferings which he may have been obliged to undergo in the process.

Insurance of the life of the deceased is no mitigation of damages; this rule of the courts is absolute. It is considered that if the deceased was sufficiently productive to enable him to pay his annual insurance premiums, it is clearly in testimony of his thrift and an element in favor of his greater usefulness, therefore his greater value to the community. Here conditions in the estimation of loss to society are still further met. It matters little to the great mass of individuals whether *that* money, the measure of value, is put into circulation *via* the insurance companies or by the individual.

Standard mortuary tables are admitted in evidence, in awarding damages for wrongful death. Such tables apply to the whole community even more clearly than to the deceased. Whatever a man's station in society, his value is dependent upon, and modified by, his life expectancy. If this be short, the guarantee of his continued usefulness is less assuring than that of a man with the prospect of a longer life.

The whole matter, therefore, naturally and finally goes back to a question of fact for the jury or court, and wherever an accidental death has been effected, the deceased is measured by his productiveness. This productiveness is directly enjoyed by his family, his employer and his associates, and through them, sooner or later in an equal degree by society at large. Therefore the measure of pecuniary loss to said family becomes a measure of damage to society. It is reasonable to believe then, that awards by courts of law for death are a safe and trustworthy estimate of the pecuniary value of the life of the deceased. There are, of course, exceptions; justice has ever been perverted; but the great mass of cases taken together, forms a reasonable basis of estimation of the value of human life.

Several of the states, however, permit their juries to assess punitive damages in cases of this character. The regulation applying to such is, in effect, as follows: "The jury may give such damages, pecuniary or exemplary, as, under the circumstances of the case, may seem to them just." Again, in some states, the maximum amount of assessment is limited by law to $5,000.00. These facts are mentioned in order to show that such damages cannot be safely included in a set of tables used for computation of values, as either the privilege of the jury, in the one case, or the statutory limitation, in the other, may prevent an award from representing a true estimate of the value of the deceased. Under the former conditions, an award of high damages may be in a large degree punitive, and only a small part of it may represent the court's estimate of the pecuniary loss. Under the latter state, an award of $5,000.00 may mean that, in the opinion of the authorities, the life was worth more, but the best that could be done was to give the maximum award.

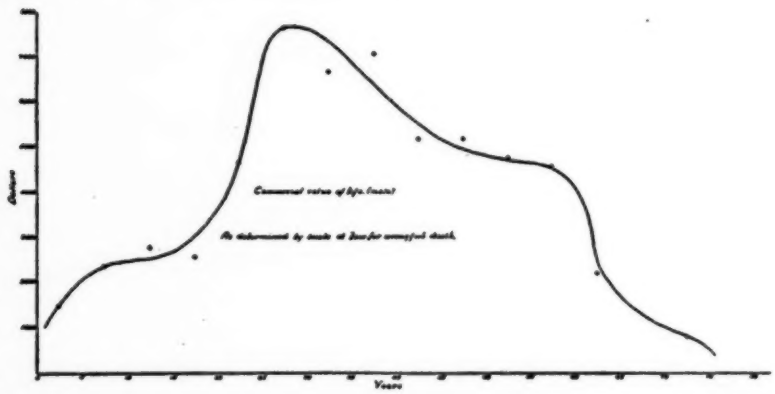
From a mass of cases which have been collected for the estimates hereinafter set forth, there have been excluded all those occurring in states in which either of the above conditions were present. Careful exclusion has also been made of cases in which there appeared unusual circumstances or conditions which rendered them non-representative of the great majority. This process has left a total of 147 cases, the decedents in which were males, of all ages, classes and conditions, some completely supporting families, and others merely contributing to the support of other persons. These cases are believed to be the result of wise judicial procedure, the awards have all been confirmed by Supreme Courts or Courts of Appeals, and they seem to form a trustworthy basis upon which to estimate.

It appears that there are not conveniently available records of suits at law, in which the decedents were females, in sufficient number to warrant the construction of a table of values for this sex. Such cases seem to be infrequent, compared with those in which the male sex figures. This is undoubtedly due to the fact that man's existence is, by reason of his occupation and inborn venturesomeness, more hazardous than woman's, and therefore presents a greater number of casualties.

Arrangement of the different cases of award for wrongful death, in the order corresponding to the age of the decedents, from the youngest to the oldest, shows a somewhat heterogeneous mass of figures, often varying considerably in the same age column. This might be expected in such an arrangement, for mankind is widely diverse. The productiveness of an individual depends upon his habits, application, thrift, mental acuteness, physical condition and many of the other personal qualities which accompany mankind. Where one indi-

vidual may possess many of these, they may be partially or altogether wanting in another, and so the judgment of juries and courts is altered to meet these conditions in the individual.

Dividing the life into age periods of five years, and combining the awards in each period, it is found that the resulting average in each period is thoroughly representative of the whole group and possesses tolerably narrow limits of probable error. Such an arrangement is shown in the accompanying diagram, in which the ordinates represent the ages of the decedents, and the abscissæ the average amount of damages awarded per case, for each age group. In this curve, it will be seen that the foci are plotted along the



center ordinate, or two and one half years away from each age-group limit. This is done in order that they may more truly represent the value of the average valuation for each five-year term, and the resulting curve may more nearly conform to the extremes, in its course from the beginning to the end of each age group.

Let us now examine this diagram and observe as closely as possible how the relative values there expressed (without regard to the actual values which they represent) conform to common observation. From the initial point, there is a rapid rise, caused by a rapidly enhancing value occasioned by the greater certainty of escape from the dangers of tender childhood. Each month and week during this period is hazardous, and as each month and year is passed in safety the risk becomes correspondingly less. Following this, is a flat portion during which the values do not change so markedly, until the age of puberty is passed. Then occurs a sharp increase, which, as it merges with the term of self-sustenance, becomes more rapid, culminating at about the age of 30 years. This is the prime of American manhood; not the period of highest productiveness, nor the age of ripest wisdom. The future is now the important feature, and there are questions of

permanence to be taken into consideration. Physical vigor usually begins to decline at this period. We are familiar with the fact that the powers of the athelete then begin to wane; champions of this age give way to younger aspirants. This means that the risk becomes greater and the confidence in future values is lowered. Therefore, even though the age of 30 is not the climax of existing usefulness, it comprises the highest combination of value and permanence.

After the age of 30, there follows a gradual decline of values until the age period 55–60 is reached, when the declivity becomes sharp, remaining so to the end. The decrease in each age group is not marked and might not be apparent when separate cases are considered, but the collective arrangement indicates with faithful accuracy all that might be expected from common observation.

Conclusions.

1. The pecuniary value of life is subject to the same economic laws as are applied to the more vulgar commodities.

2. In courts of law, the measure of an individual's productiveness, which is the measure of his value, receives the most careful scrutiny; therefore the decisions of such courts, where existing statutes permit, are trustworthy in determining an individual's value to his family.

3. The pecuniary value of a life to its relatives represents its pecuniary value to society.

4. Damages given for wrongful death are such that they can be represented by an average in different age groups, with only narrow limits of probable error.

5. The relation of these age-group values, one to the other, is supported by common observation and statistical reasoning.

INSTINCT,

WITH ORIGINAL OBSERVATIONS ON YOUNG ANIMALS.*

By DOUGLAS A. SPALDING.

THE exquisite skill and accurate knowledge observable in the lives of the lower animals, which men generally have regarded as instinctive—born with them—have ever been subjects of wonder. In the hands of the natural theologian, whose armory has been steadily impoverished in proportion as mystery has given way before science, instinct is still a powerful weapon. When the divine expatiates on the innate wisdom and the marvelous untaught dexterity of beasts, birds, and insects, he is in little danger of being checked by the men of science. His learned enemies are dumb, when in triumph he asks the old question:

> Who taught the nations of the field and wood
> To shun their poison and to choose their food?
> Prescient, the tides or tempests to withstand,
> Build on the wave, or arch beneath the sand?

The very little that our psychologists have done for instinct may be told in a few words. The only theory of instinct, of the nature of an explanation, is that put forward by Mr. Herbert Spencer as part of his philosophy of evolution; but, as a theory, it is only beginning to be understood and appreciated among scientific men; while some eminent thinkers question the reality of the phenomena to be explained. Professor Bain, our other psychologist, and his able following of trained disciples, simply discredit the alleged facts of instinct. Unfortunately, however, instead of putting the matter to the test of observation and experiment, they have contented themselves with criticizing the few accidental observations that have been recorded, and with arguing against the probability of instinctive knowledge. In defending the Berkeleian Theory of Vision, Professor Bain, in answer to the assertion that the young of the lower animals manifest an instinctive perception of distance by the eye, contends that 'there does not exist a body of careful and adequate observations on the early movements of animals.' Writing long ago on the same subject, Mr. Mill also, while admitting that 'the facts relating to the young of the lower animals have been long felt to be a real stumbling-block in the way of the theory,' maintains that 'our knowledge of the mental operations of animals is too imperfect to enable

* Reprinted from *Macmillan's Magazine*, February, 1873.

us to affirm positively that they have this instinct.' Denying the facts, however, was not Mr. Mill's mode of saving the theory. He was rather of opinion that the 'animals have to us an inexplicable facility both of finding and selecting the objects which their wants require.' How very inexplicable, he conceives, their mental operations may possibly be, may be gathered from the fact of his suggesting an experiment to ascertain whether a blind duckling might not find the water as readily as one having sight. The position of psychologists of the too purely analytical school, however, is not that the facts of instinct are inexplicable; but that they are incredible. This view is set out most explicitly in the article on 'instinct' in 'Chambers's Encyclopædia.' Thus:

> "It is likewise said that the chick recognizes grains of corn at first sight, and can so direct its movements as to pick them up at once; being thus able to know the meaning of what it sees, to measure the distance of objects instinctively, and to graduate its movements to that knowledge—all which is, in the present state of our acquaintance with the laws of mind, wholly incredible."

And it is held that all the supposed examples of instinct may be—for anything that has yet been observed to the contrary—nothing more than cases of rapid learning, imitation or instruction.

Thus it would appear that with regard to instinct we have yet to ascertain the facts. With a view to this end, I have made many observations and experiments, mostly on chickens. The question of instinct, as opposed to acquisition, has been discussed chiefly in connection with the perceptions of distance and direction by the eye and the ear. Against the instinctive character of these perceptions it is argued, that as distance means movement, locomotion, the very essence of the idea is such as can not be taken in by the eye or ear; that what the varying sensations and feelings of sight and hearing correspond to, must be got at by moving over the ground—by experience. On the other hand, it is alleged that, though as regards man the prolonged helplessness of infancy stands in the way of the observer, we have only to look at the young of the lower animals to see that as a matter of fact they do not require to go through the process of learning the meaning of their sensations in relation to external things; that chickens, for example, run about, pick up crumbs, and follow the call of their mother *immediately* on leaving the shell. For putting this matter to the test of experiment, chickens, therefore, are most suitable and convenient subjects. I have observed and experimented on more than fifty chickens, taking them from under the hen while yet in the eggs. But of these, not one on emerging from the shell was in a condition to manifest an acquaintance with the qualities of the outer world. On leaving the shell they are wet and helpless; they struggle with their legs, wings, and necks, but are unable to stand or hold up their heads. Soon, however, they may be distinctly seen and felt pressing against and endeavoring to keep in

contact with any warm object. They advance very rapidly. I have seen them hold up their heads well, peck at objects, and attempt to dress their wings when only between four and five hours old. But there is no difficulty in conceiving that, with great spontaneity and a strong power of association, much might be learned in four or five hours. Professor Bain is of opinion, from observations of his own on a newly dropped lamb, that 'a power that the creature did not at all possess naturally, got itself matured as an acquisition in a few hours.' Accordingly, in the absence of precautions, the time that must elapse before chickens have acquired enough control over their muscles to enable them to give evidence as to their instinctive power of interpreting what they see and hear, would suffice to let in the contention that the eye and the ear may have had opportunities of being educated. To obviate this objection with respect to the eye, I had recourse to the following expedient. Taking eggs just when the little prisoners had begun to break their way out, I removed a piece of the shell, and before they had opened their eyes drew over their heads little hoods, which, being furnished with an elastic thread at the lower end, fitted close round their necks. The material of these hoods was in some cases such as to keep the wearers in total darkness; in other instances it was semi-transparent. Some of them were close at the upper end, others had a small aperture bound with an elastic thread, which held tight round the base of the bill. In this state of blindness—the blindness was very manifest—I allowed them to remain from one to three days. The conditions under which these little victims of human curiosity were first permitted to see the light were then carefully prepared. Frequently the interesting little subject was unhooded on the center of a table covered with a large sheet of white paper, on which a few small insects, dead and alive, had been placed. From that instant every movement, with the date thereof, as shown by the watch, was put on record. Never in the columns of a Court Journal were the doings of the most royal personage noted with such faithful accuracy. This experiment was performed on twenty separate chickens at different times, with the following results. Almost invariably they seemed a little stunned by the light, remained motionless for several minutes, and continued for some time less active than before they were unhooded. Their behavior, however, was in every case conclusive against the theory that the perceptions of distance and direction by the eye are the result of experience, of associations formed in the history of each individual life. Often at the end of two minutes they followed with their eyes the movements of crawling insects, turning their heads with all the precision of an old fowl. In from two to fifteen minutes they pecked at some speck or insect, showing not merely an instinctive perception of distance, but an original ability to judge, to measure distance, with something like infallible accuracy. They did not attempt to seize things beyond their

reach, as babies are said to grasp at the moon; and they may be said to have invariably hit the objects at which they struck—they never missed by more than a hair's breadth, and that, too, when the specks at which they aimed were no bigger, and less visible, than the smallest dot of an *i*. To seize between the points of the mandibles at the very instant of striking seemed a more difficult operation. I have seen a chicken seize and swallow an insect at the first attempt: most frequently, however, they struck five or six times, lifting once or twice before they succeeded in swallowing their first food. The unacquired power of following by sight was very plainly exemplified in the case of a chicken that, after being unhooded, sat complaining and motionless for six minutes, when I placed my hand on it for a few seconds. On removing my hand the chicken immediately followed it by sight backward and forward and all round the table. To take, by way of example, the observations in a single case a little in detail: A chicken that had been made the subject of experiments on hearing, was unhooded when nearly three days old. For six minutes it sat chirping and looking about it; at the end of that time it followed with its head and eyes the movements of a fly twelve inches distant; at ten minutes it made a peck at its own toes, and the next instant it made a vigorous dart at the fly, which had come within reach of its neck, and seized and swallowed it at the first stroke; for seven minutes more it sat calling and looking about it, when a hive-bee coming sufficiently near was seized at a dart and thrown some distance, much disabled. For twenty minutes it sat on the spot where its eyes had been unveiled without attempting to walk a step. It was then placed on rough ground within sight and call of a hen with a brood of its own age. After standing chirping for about a minute, it started off towards the hen, displaying as keen a perception of the qualities of the outer world as it was ever likely to possess in after life. It never required to knock its head against a stone to discover that there was 'no road that way.' It leaped over the smaller obstacles that lay in its path and ran round the larger, reaching the mother in as nearly a straight line as the nature of the ground would permit. This, let it be remembered, was the first time it had ever walked by sight.*

* Since writing this article, I see it stated in Mr. Darwin's new book, 'The Expression of the Emotions in Man and Animals,' that "the wonderful power which a chicken possesses only a few hours after being hatched, of picking up small particles of food, seems to be started into action through the sense of hearing; for, with chickens hatched by artificial heat, a good observer found that 'making a noise with a fingernail against a board, in imitation of the hen-mother, first taught them to peck at their meat.'" My own observations give no countenance whatever to this view: (1) I have frequently observed chickens finally hatched in a flannel nest over a jar of hot water and left undisturbed for

It would be out of place here to attempt to indicate the full psychological bearing of these facts. But this much may be affirmed, that they put out of court all those who are prepared only to argue against the instinctive perception by the eye of the primary qualities of the external world. When stripped of all superfluous learning, the argument against this and every other alleged case of instinctive knowledge is simply that it is unscientific to assume an instinct when it is possible that the knowledge in question may have been acquired in the ordinary way. But the experiments that have been recounted are evidence that prior to experience chickens behave as if they already possessed an acquaintance with the established order of nature. A hungry chick that never tasted food is able, on seeing a fly or a spider for the first time, to bring into action muscles that were never so exercised before, and to perform a series of delicately adjusted movements that end in the capture of the insect. This I assert as the result of careful observation and experiment; and it cannot be answered but by observation and experiment at least as extensive. It is no doubt common for scientific men to discredit new facts, for no other reason than that they do not fit with theories that have been raised on too narrow foundations; but when they do this they are only geologists, or psychologists—they are not philosophers.

Before passing to the perceptions of the ear, it may be mentioned that, instead of hooding chickens, which had the advantage of enabling me to make many interesting observations on them when in a state of blindness, I occasionally put a few eggs, when just chipped, into a flannel bag made for the purpose. In this bag the hatching was completed artificially, and the chickens allowed to remain in the dark from one to three days. When placed in the light they deported themselves as regards sight in the manner already described. For the purpose

a few hours, begin, immediately after the covering was removed, and while they still sat nestling together, to pick at each other's beaks and at specks of oatmeal when these were dropped on them, all noise being as far as possible avoided. (2) Each of the twenty chickens made subjects of the experiment described in the text, began to eat without any assistance from the sense of hearing; the greatest possible stillness being maintained and required during the experiment. (3) Chickens picked up food though rendered deaf while yet in the shell. One of these, deprived of both sight and hearing at its birth, was unhooded when three days old, and nine minutes after it vigorously pursued a large blue fly a distance of two feet, pecking at it several times: the bird proved perfectly deaf. Another with its ears similarly closed, was taken from the dark when a day and a half old, and when an experiment was being tried to ascertain whether it was perfectly deaf—which it turned out to be—it began to pick up and swallow small crumbs. What in this case really surprised me was that, the gum employed in closing its ears having also sealed up one of its eyes, it nevertheless picked up crumbs by sight of its one eye almost if not altogether as well as if it had had two.

of merely testing the perceptions of the eye or the ear this is by far the easier experiment. The hooding process requires considerable delicacy of manipulation, and the chickens are very liable to be injured.

With respect now to the space perceptions of the ear, which, in man at least, even Mr. Spencer regards as acquired by each individual. Chickens hatched and kept in the said bag for a day or two, when taken out and placed nine or ten feet from a box in which a hen with chicks were concealed, after standing for a minute or two, uniformly set off straight for the box in answer to the call of the hen, which they had never seen and never before heard. This they did, struggling through grass and over rough ground, when not yet able to stand steadily on their legs. Nine chickens were thus experimented upon, and each individual gave the same positive results, running to the box scores of times, and from every possible position. To vary the experiment I tried the effect of the mother's voice on hooded chickens. These, when left to themselves, seldom made a forward step, their movements were round and round, and backward; but when placed within five or six feet of the mother, they, in answer to her call, became much more lively, began to make little forward journeys, and soon followed her by sound alone, though, of course, blindly, keeping their heads close to the ground and knocking against everything that lay in their path. Only three chickens were made subjects of this experiment. Another experiment consisted in rendering chickens deaf for a time by sealing their ears with several folds of gum paper before they had escaped from the shell. I tried at different times to stop the ears of a good many in this way, but a number of them got the papers off, others were found not quite deaf, and only three remained perfectly indifferent to the voice of the mother when separated from them by only an inch board. These had their ears opened when between two and three days old, and on being placed within call of the mother hidden in a box, they, after turning round a few times, ran straight to the spot whence came what must have been very nearly, if not actually, the first sound they had ever heard. It seems scarcely necessary to make any comment on these facts. They are conclusive against the theory that, in the history of each life, sounds are at first but meaningless sensations; that the direction of the sounding object, together with all other facts concerning it, must be learned entirely from experience.

If now it be taken as established that in the perceptions of the eye and the ear, chickens at least manifest an instinctive knowledge of the relations and qualities of external things, the popular belief that the special knowledge, the peculiar art and skill, so marked in the various species of animals, come to them mostly without the labor of acquisition, is at once freed from all antecedent improbability. In the way of direct evidence, the little that I have been able to observe in this wide

field goes to prove that the current notions are in accordance with fact. We have seen that chickens follow the call of their mother before they have had any opportunity of associating that sound with pleasurable feelings; and one or two observations, which must be taken for what they are worth, support the general opinion that they have an equally instinctive dread of their more deadly enemies. When twelve days old one of my little *protégés,* while running about beside me, gave the peculiar chirr whereby they announce the approach of danger. I looked up, and behold a sparrow-hawk was hovering at a great height over head. Having subsequently procured a young hawk, able to take only short flights, I made it fly over a hen with her first brood, then about a week old. In the twinkling of an eye most of the chickens were hid among grass and bushes. The hen pursued, and scarcely had the hawk touched the ground, about twelve yards from where she had been sitting, when she fell upon it with such fury that it was with difficulty that I was able to rescue it from immediate death. Equally striking was the effect of the hawk's voice when heard for the first time. A young turkey, which I had adopted when chirping within the uncracked shell, was on the morning of the tenth day of its life eating a comfortable breakfast from my hand, when the young hawk, in a cupboard just beside us, gave a shrill chip, chip, chip. Like an arrow the poor turkey shot to the other side of the room, and stood there motionless and dumb with fear, until the hawk gave a second cry, when it darted out at the open door right to the extreme end of the passage, and there, silent and crouched in a corner, remained for ten minutes. Several times during the course of that day it again heard these alarming sounds, and in every instance with similar manifestations of fear. Unfortunately, my hawk coming to an untimely end, I was prevented from proceeding with observations of this class. But these few were so marked and unmistakable in their character that I have thought them worth recording.

There are instincts, however, yet to be mentioned, concerning the reality of which I have thoroughly satisfied myself. The early attention that chickens give to their toilet is a very useful instinct, about which there can be no question. Scores of times I have seen them attempt to dress their wings when only a few hours old—indeed as soon as they could hold up their heads, and even when denied the use of their eyes. The art of scraping in search of food, which, if anything, might be acquired by imitation—for a hen with chickens spends the half of her time in scratching for them—is nevertheless another indisputable case of instinct. Without any opportunities of imitation, when kept quite isolated from their kind, chickens began to scrape when from two to six days old. Generally, the condition of the ground was suggestive; but I have several times seen the first attempt, which consists of a sort

of nervous dance, made on a smooth table. As an example of unacquired dexterity, I may mention that on placing four ducklings a day old in the open air for the first time, one of them almost immediately snapped at and caught a fly on the wing. More interesting, however, is the deliberate art of catching flies practised by the turkey. When not a day and a half old I observed the young turkey already spoken of slowly pointing its beak at flies and other small insects without actually pecking at them. In doing this, its head could be seen to shake like a hand that is attempted to be held steady by a visible effort. This I observed and recorded when I did not understand its meaning. For it was not until after, that I found it to be the invariable habit of the turkey, when it sees a fly settled on any object, to steal on the unwary insect with slow and measured step until sufficiently near, when it advances its head very slowly and steadily till within an inch or so of its prey, which is then seized by a sudden dart. If all this can be proved to be instinct, few, I think, will care to maintain that *anything* that can be learned from experience *may* not also appear as an intuition. The evidence I have in this case, though not so abundant as could be wished, may yet, perhaps, be held sufficient. I have mentioned that this masterpiece of turkey cleverness when first observed was in the incipient stage, and, like the nervous dance that precedes the actual scraping, ended in nothing. I noted it simply as an odd performance that I did not understand. The turkey, however, which was never out of my sight except when in its flannel bag, persisted in its whimsical pointing at flies, until before many days I was delighted to discover that there was more in it than my philosophy had dreamt of. I went at once to the flock of its own age. They were following a common hen, which had brought them out; and as there were no other turkeys about the place, they could not possibly learn by imitation. As the result, however, of their more abundant opportunities, I found them already in the full and perfect exercise of an art—a cunning and skilful adjusting of means to an end—bearing conspicuously the stamp of experience. But the circumstances under which these observations were made left me no room for the opinion that the experience, so visible in their admirable method of catching flies, was original, was the experience, the acquisition of those individual birds. To read what another has observed is not, however, so convincing as to see for oneself, and to establish a case so decisive more observation may reasonably be desired; at the same time, it can scarcely be attempted to set aside the evidence adduced, on the ground of improbability, for the *fact* of instinct: all that is involved in this more striking example has, we venture to think, been sufficiently attested.

A few manifestations of instinct still remain to be briefly spoken of. Chickens as soon as they are able to walk will follow any moving object.

And, when guided by sight alone, they seem to have no more disposition to follow a hen than to follow a duck, or a human being. Unreflecting on-lookers, when they saw chickens a day old running after me, and older ones following me miles and answering to my whistle, imagined that I must have some occult power over the creatures, whereas I simply allowed them to follow me from the first. There is the instinct to follow; and, as we have seen, their ear prior to experience attaches them to the right object. The advantage of this arrangement is obvious. But instincts are not conferred on any principle of supplying animals with arts very essential to them, and which they could not very well learn for themselves. If there is anything that experience would be sure to teach chickens, it would be to take care when they had got a piece of food not to let their fellows take it from them, and from the very first they may be seen to run off with a worm, pursued by all their companions. But this has been so stamped in their nature that, when they have never seen one of their kind, nor ever been disturbed in the enjoyment of a morsel, they nevertheless, when they get something larger than can be swallowed at once, turn round and run off with it.

Another suggestive class of phenomena that fell under my notice may be described as imperfect instincts. When a week old my turkey came on a bee right in its path—the first, I believe, it had ever seen. It gave the danger chirr, stood for a few seconds with outstretched neck and marked expression of fear, then turned off in another direction. On this hint I made a vast number of experiments with chickens and bees. In the great majority of instances the chickens gave evidence of instinctive fear of these sting-bearing insects; but the results were not uniform, and perhaps the most accurate general statement I can give is, that they were uncertain, shy and suspicious. Of course to be stung once was enough to confirm their misgivings forever. Pretty much in the same way did they avoid ants, especially when swarming in great numbers.

Probably enough has been said to leave no doubt in minds free from any bias on the subject, that in the more important concerns of their lives the animals are in great part guided by knowledge that they individually have not gathered from experience. But equally certain is it that they do learn a great deal, and exactly in the way that we are generally supposed to acquire all our knowledge. For example, every chicken, as far as my observations go, has to learn not to eat its own excrement. They made this mistake invariably; but they did not repeat it oftener than once or twice. Many times they arrested themselves when in the very act, and went off shaking their heads in disgust, though they had not actually touched the obnoxious matter. It also appeared that, though thirsty, they did not recognize water by sight, except perhaps in the form of dew-drops on the grass; and they had to

some extent to learn to drink. Their first attempts were awkward; instead of dipping in their beaks, they pecked at the water, or rather at specks in the water, or at the edge of the water. All animals have a capacity to learn; each individual must learn the topography of its locality, and numerous other facts. Many dogs, horses and elephants may be able to learn more than some men. But I have no doubt that observation will bear out the popular belief that what may be called the professional knowledge of the various species—those special manifestations of practical skill, dexterity and cunning that mark them off from each other, no less clearly than do the physical differences whereon naturalists base their classifications—is instinctive, and not acquired. As we shall see, the creatures have not in a vast multitude of instances the opportunity to acquire these arts. And if they had the opportunity, they have not individually the capacity to do so, even by way of imitation. We have seen as a matter of fact that it is by instinct that the chicken, and, I may now add, the turkey, scratch the surface of the earth in search of insects; also, that the turkey has a method of catching flies so remarkably clever that it cannot be witnessed without astonishment. Now, chickens like flies no less than turkeys, and, though with less success, often try to catch them. But it is a significant fact that they do not copy the superior art. To give every opportunity for imitation, I placed a newly-hatched chicken with my turkey, when the latter was eleven days old. The two followed me about for several weeks, and when I deserted them they remained close companions throughout the summer, neither of them ever associating with the other poultry. But the chicken never caught the knowing trick of its companion—seemed, indeed, wholly blind to the useful art that was for months practised before its eyes.

Before passing to the theory of instinct, it may be worthy of remark that, unlooked for, I met with in the course of my experiments some very suggestive, but not yet sufficiently observed, phenomena; which, however, have led me to the opinion that not only do the animals learn, but they can also forget—and very soon—that which they never practised. Further, it would seem that any early interference with the established course of their lives may completely derange their mental constitution, and give rise to an order of manifestations perhaps totally and unaccountably different from what would have appeared under normal conditions. Hence I am inclined to think that students of animal psychology should endeavor to observe the unfolding of the powers of their subjects in as nearly as possible the ordinary circumstances of their lives. And perhaps it may be because they have not all been sufficiently on their guard in this matter, that some experiments have seemed to tell against the reality of instinct. Without attempting to prove the above propositions, one or two facts may be mentioned. Untaught, the new-born

babe can suck—a reflex action; and Mr. Herbert Spencer describes all instinct as 'compound reflex action'; but it seems to be well known that if spoon-fed, and not put to the breast, it soon loses the power of drawing milk. Similarly a chicken that has not heard the call of the mother until eight or ten days old then hears it as if it heard it not. I regret to find that on this point my notes are not so full as I could wish, or as they might have been. There is, however, an account of one chicken that could not be returned to the mother when ten days old. The hen followed it, and tried to entice it in every way; still it continually left her and ran to the house or to any person of whom it caught sight. This it persisted in doing, though beaten back with a small branch dozens of times, and indeed cruelly maltreated. It was also placed under the mother at night, but it again left her in the morning. Something more curious, and of a different kind, came to light in the case of three chickens that I kept hooded until nearly four days old —a longer time than any I have yet spoken of. Each of these on being unhooded evinced the greatest horror of me, dashing off in the opposite direction whenever I sought to approach it. The table on which they were unhooded stood before a window, and each in its turn beat against the glass like a wild bird. One of them darted behind some books, and squeezing itself into a corner, remained cowering for a length of time. We might guess at the meaning of this strange and exceptional wildness; but the odd fact is enough for my present purpose. Whatever might have been the meaning of this marked change in their mental constitution—had they been unhooded on the previous day they would have run to me instead of from me—it could not have been the effect of experience; it must have resulted wholly from changes in their own organization.

The only theory in explanation of the phenomena of instinct that has an air of science about it, is Mr. Spencer's doctrine of Inherited Acquisition. The laws of association explain our intellectual operations, and enable us to understand how all our knowledge may be derived from experience. A chicken comes on a bee, and imagining it has found a dainty morsel, seizes the insect, but is stung, and suffers badly. Henceforth bees are avoided; they can be neither seen nor heard without a shudder of fear. Now, if we can realize how such an association as this—how what one individual learns by experience may, in any degree, be transmitted to the progeny of that individual—we have a key to the mystery of instinct. Instinct in the present generation is the product of the accumulated experiences of past generations. The plausibility of this hypothesis, however, is not appreciated by the majority of even the educated portion of the community. But the reason is not far to seek. Educated men, even materialists—their own positive statements to the contrary notwithstanding—have not yet quite escaped from the habit

of regarding mind as independent of bodily organization. Hence it is, that while familiar with the idea of physical peculiarities passing by inheritance from one generation to another, they find it difficult to conceive how anything so impalpable as fear at the sight of a bee should be transmitted in the same way. Obviously, this difficulty is not consistent with a thorough belief in the intimate and invariable dependence of all kinds of mental facts on nervous organization. Let us, if possible, make this clear. The facts of mind that make up the stream of an individual life differ from material things in this important respect, that whereas the latter can be stored up, volitions, thoughts, and feelings, as such, cannot. Facts of consciousness cannot be thought of as packed away like books in a library. They have to be forever produced, created, one after another; and when gone they are out of existence. Whatever associations may be formed among these, must depend for their permanence on the corresponding impress given to the nervous organism; and why should not this, which is purely physical, be subject to the law of heredity? Look at a friend as he lies in unconscious sleep. His sovereigns are in his pocket, but where is his stock of ideas? Where is all that he has learned from experience? You have simply a living machine; but such a machine that it can wake and exhibit all the phenomena of what we call a well-informed and cultivated mind. Suppose, now, that while you stand by, another organism, the same in every particle and fiber, is by some mysterious process formed direct from its elements. Outwardly you cannot tell the one from the other; but wake them and how will it be? Even then, will not the one being recognize you, and then be as completely and indistinguishably your friend as the other? Will not the newly created man, by virtue of his identical material organization, possess the mind and character, the knowledge and feelings, the past, in a word, the personal identity of the other? I have made this extreme supposition in order that no doubt may be entertained as to the shape in which I hold the doctrine that for every fact of mind there is a corresponding fact of matter, and that, given the material fact, whether produced by repeated experiences in the life history of the individual, or inherited from parents, the corresponding mental fact will be the same. If this view be admitted, there can be no difficulty in conceiving how entrance into life on the part of the animals may be a waking up in a world with which they are, in greater or less degree, already acquainted! Instinct, looked at from its physical side, may be conceived to be, like memory, a turning on of the 'nerve currents' on already established tracks: for no reason, we presume, can be suggested why those modifications of brain matter that, enduring from hour to hour and from day to day, render acquisition possible, should not, like any other physical peculiarity, be transmitted from parent to offspring. That they are so transmitted is all but proved by

the facts of instinct, while these in their turn receive their only rational explanation in this theory of inherited acquisition. But the difficulty of the undisciplined mind lies, as we have said, in an inability to grasp the full significance of the doctrine that, in an individual life, it is the physical part alone that endures from day to day; that, strictly speaking, we cannot feel the same feeling or think the same thought twice over; that only as by pulling the bell-cord to-day we can, in the language of ordinary discourse, produce the sound we heard yesterday, can we, while the established connections among the nerves and nerve centers hold, live our experiences over again.

This doctrine of inherited acquisition, then, is, to say the least, a good working hypothesis in explanation of all those facts of instinct that may be conceived as built up, compounded out of, the accumulated experiences of innumerable generations. So far good. But it will occur to every reader that the peculiar depths of animal psychology are not yet explored. Two classes of phenomena still lie in the dark. First, there are the many extraordinary and exceptional feats of dogs and other animals, which seem to be constantly falling under the observation of everybody except the few that are interested in these matters. Second, all the more wonderful instincts, especially those of insects, are such that it is hard, if at all possible, to conceive how they ever could have been derived from experience.

With regard to the first, it is not desirable to say much. Though volumes of marvelous stories have been written, I am not aware that any careful experiments have been tried, and, as the performances in question are of an exceptional character, it is perhaps but scientific caution not as yet to put too much stress on them. For my own part, though I have been very intimate with dogs, I have been singularly unfortunate in having never witnessed any of their more incomprehensible clairvoyant-like achievements. I have known them to do many surprising things, but I have always found that they had, or might have had, something to go upon—enough, coupled with quick intelligence, to account for their exploits. What may be said in this connection, if, indeed, it be prudent to say anything, is that, while we certainly cannot have all the data of experience from without of all the vastly different living things which people the earth, the air, and the ocean—while we certainly can have no trace of many feelings that arise from changes in the organisms of the different creatures, and which, instinctively interpreted, start them on lines of action—a host of statements, generally accepted as fact, suggest the opinion that even such animals as dogs, are alive to, conscious, sensible of influences that scarcely affect us, or wholly escape our cognition. If this be so, they have a basis of experience from which to start in their calculations that we want, and, if so, well may their actions seem to us, as Mr. Mill said, hopelessly inexpli-

cable. Take, not the most remarkable, but the best authenticated example of this class—the frequently alleged fact of dogs and other animals returning in a straight line, or by the most direct routes, through districts they had never before traversed, to places from which they had been taken by devious tracks, and even shut up in close boxes. To most people this is a phenomenon sufficiently incomprehensible. They are certain they themselves could do nothing at all like it. But there is in some men what may be just a hint of this faculty. Most people that have lived only in cities are very soon lost in a strange and trackless district, and still sooner in a pathless wood; in the one case, after wandering this way and that for a few hours, in the other, after merely turning round a few times, they can tell nothing of the direction whence they came. But all men are not so easily lost; some, without consciously making notes, retain, after long wandering in such situations, a strong and often accurate impression, not of the ground they have gone over, but of the direction in which lies the place whence they started. Without attempting to throw any light on the mental chemistry of this perception, we would submit that in it may perhaps be found a clue to the mystery of those astonishing home-journeys of dogs, sheep, cats, pigeons, bees, etc., of which hundreds are on record.

It is, however, with the other dark enigma that we are more specially concerned. We do not think it necessary to examine the proof of the actuality of such marvelous instincts as those of bees and wasps. But for the too fond love of a theory we venture to think none would doubt the reality, or the instinctive character, of their "far-sighted," or, more correctly, blind provisions for the future. The problem before us is not whether, for example, the male of the fish *Arius* does, and by instinct, hatch the eggs of the female in his mouth, but how such a singular mode of incubation ever had a beginning? Perhaps the most widely known instance of this class of instincts is the provision of the solitary wasp for the worm that will issue from her egg after her own death. She brings grubs—food that as a wasp she never tasted—and deposits them over the egg, ready for the larva she will never see. The life history of every insect exhibits instincts of this perplexing description. Witness the caterpillar, how at the proper time it selects a suitable situation and spins for itself a silken cocoon. It may be admitted at once that the creatures, as *we behold them*, never could have lived to acquire such instincts by any process of experience and inheritance of which we can conceive. Nor let it be supposed that it is only in the insect world, where all is so strange, that instincts are to be met with so essential to lives of the individuals or their progeny that without them the creatures in their present shape could never have existed. Of this kind are the first movements observable in the life of a bird, and which take place within the shell. I have often observed the self-delivery

of the chicken. The prison wall is not burst in pieces by spontaneous, random struggles. By a regular series of strokes the shell is cut in two—chipped right round in a perfect circle, some distance from the great end. Moreover, the bird has a special instrument for this work, a hard, sharp horn on the top of the upper mandible, which being required for no other purpose disappears in a few days. Obviously each individual bird no more acquires the art of breaking its way out than it furnishes itself with the little pick-hammer used in the operation; and it is equally clear that a bird could have never escaped from the egg without this instinct. Again, how were eggs hatched before birds had acquired the instinct to sit upon them? Or who will throw light on the process of such an acquisition? Nor are the subsequent phenomena easier of explanation. A fowl that never before willingly shared a crumb with a companion, will now starve herself to feed her chickens, which she calls by a language she never before used—may have never even heard—but which they are born to understand. Once more, it is clearly because she cannot do otherwise that a she-rabbit, when with her first young, digs a hole in the earth away from her ordinary habitation, and there builds a nest of soft grass, lined with fur stripped from her own body. But how as to the origin of this habit?

We need not accumulate examples of seemingly unfathomable instincts. And it may be confessed at once that in the present state of our knowledge it would be hopeless to attempt to guess at the kinds of experiences that may have originally, when the creatures wore different shapes and lived different lives, wrought changes in their nervous systems that, enduring and being modified through many changes of form, have given to the living races the physical organizations of which these wonderful instincts are the corresponding mental facts. Nor, perhaps, can it be confidently asserted that in experience and heredity we have all the terms of the problem. The little we can say is that though in the dark we need not consider ourselves more in the dark as to the origin of those strange instincts than we are concerning the origin of those wonderful organs of astonishing and exquisite mechanism that, especially among the insects, are the instruments of those instincts. Nay, more, if the view we have put forward concerning the connection between mental manifestations and bodily organization be correct, the question of the origin of these mysterious instincts is not more difficult than, or different from, but is the same with, the problem of the origin of the physical structure of the creatures; for, however they may have come by their bodies, they cannot fail to have the minds that correspond thereto. When, as by a miracle, the lovely butterfly bursts from the chrysalis full-winged and perfect, and flutters off a thing of soft and gorgeous beauty, it but wakes to a higher life, to a new mode of existence, in which, strange though it may sound, it

has, for the most part, nothing to learn; *because* its little life flows from its organization like melody from a music box. But we need not enlarge on this a second time.

In seeking to understand the phenomena of instinct we of course get the full benefit of the law of Natural Science, which though it throws no light on the origin of anything, mental or physical—for, as Mr. Darwin says, it 'has no relation whatever to the primary cause of any modification of structure'—nevertheless helps us to understand the existence of instincts far removed from the circumstances or conditions of life under which they could have been acquired. Suppose a Robinson Crusoe to take, soon after his landing, a couple of parrots, and to teach them to say in very good English, "How do you do, sir?"—that the young of these birds are also taught by Mr. Crusoe and their parents to say, "How do you do, sir?"—and that Mr. Crusoe, having little else to do, sets to work to prove the doctrine of Inherited Association by direct experiment. He continues his teaching, and every year breeds from the birds of the last and previous years that say "How do you do sir?" most frequently and with the best accent. After a sufficient number of generations his young parrots, continually hearing their parents and a hundred other birds saying "How do you do, sir?" begin to repeat these words so soon that an experiment is needed to decide whether it is by instinct or imitation; and perhaps it is part of both. Eventually, however, the instinct is established. And though now Mr. Crusoe dies, and leaves no record of his work, the instinct will not die, not for a long time at least; and if the parrots themselves have acquired a taste for good English the best speakers will be sexually selected, and the instinct will certainly endure to astonish and perplex mankind, though in truth we may as well wonder at the crowing of the cock or the song of the skylark. Again, turkeys have an instinctive art of catching flies, which, it is manifest, the creatures in their present shape may have acquired by experience. But suppose the circumstances of their life to change; flies steadily become more abundant, and other kinds of food scarcer: the best fly-catchers are now the fittest to live, and each generation they are naturally selected. This process goes on, experience probably adding to the instinct in ways that we need not attempt to conceive, until a variety or species is produced that feeds on flies alone. To look at, this new bird will differ considerably from its turkey ancestors; for change in food and in habits of life will have affected its physical conformation, and every useful modification of structure will have been preserved by natural selection. My point however is, that thus, by no inconceivable steps, would be produced a race of birds depending for all their food on an instinctive art, which they, as then constituted, could never have acquired, because they never could have existed without it.

No doubt, to the many, who love more to gaze and marvel than to question and reflect, all this will seem miserably inadequate as a clue to one of the greatest mysteries of life. But enough, if I have indicated my view of how the most inexplicable of instincts may have had their origin; or rather, if I have shown how our utter inability to trace them back to their origin tells nothing against the probability that they all came into existence in accordance with those laws of acquisition and heredity that we now see operating before our eyes. We cannot tell how the pupa of the dragon-fly came by the instinct that prompts it to leave the water and hang itself up to dry. But we may be able to explain this quite as soon as to unveil the origin of the hooks by which it hangs itself up. And if ever human intelligence should so trace the evolution of living forms as to be able to say, "Thus was developed the bill-scale wherewith birds now break their way out of the shells," it will probably be able to add, "and these were the experiences to which we must trace the instinct that makes every little bird its own skilful accoucheur."

EDUCATIONAL VALUE OF PHOTOMICROGRAPHY.

BY ARTHUR CURTIS SCOTT,
MADISON, WISCONSIN.

THE part of the universe which the penetrating power of the microscope reveals to the student of nature, though concerned with the infinitesimal, equals the macroscopic portion in magnitude and significance.

Modern scientific consideration recognizes the fact that no more accurate method of research can be concentrated on the question of origin, cyclic changes in development and existing structure of various forms of matter, both organic and inorganic, than that of their minute examination under the microscope. It is a familiar fact that early investigators with this instrument, as well as many at the present time, exhibit as results of their work drawings of the objects examined. While these pictures made with the camera lucida may be reasonably exact when drawn by a careful investigator under the best conditions, it is true that they are frequently inaccurate under ordinary circumstances, and when numerous reproductions are desired the photomicrograph is largely superseding the laborious work of the draftsman.

It is probable that the application of photography to the reproduction of microscopic structure has largely been due to the demand for unmodified and unprejudiced exactness of detail. Again the photographic plate is more sensitive and more efficient than the retina, for not only is the human eye easily fatigued, but it is quite unable to regard slight differences of illumination, or to differentiate the most minute characteristics of specimens. While it is a fact that the plate is most sensitive to light of a certain color and intensity, it is also true that the requirements can be readily obtained, and that the silver salt is able to indicate the action of light that fails to stimulate the sense of vision. The existence of funiculi in the coma-bacilli of Asiatic cholera, for example, was proved by the aid of photography after repeated failures to discover them by other means.

The middle of the nineteenth century marks the beginning of attention to photomicrography when Mayer of Frankfort devised apparatus for this work. Since that time wonderful advance has been made both in photography and microscopy, and we now may obtain not only extremely rapid and color sensitive plates, with readily modified developers that allow a considerable latitude of exposure, but micro-

scopes of the highest perfection mechanically, and closely approaching that standard, optically. It may be said in this connection also that though apparatus of excellent quality is thus readily obtained, yet a reasonably accurate knowledge of the optical principles involved and of photographic manipulation is quite necessary to insure satisfactory results. In fact it is the writer's conclusion, after some years' experience connected with the various branches of scientific photography, that no more difficult problem has presented itself than the production of a thoroughly satisfactory photomicrograph of a specimen magnified to 2,000 diameters.

Probably many failures in the work are directly traceable to the use of inferior microscopes, and a few points noticed here may be interesting and possibly instructive.

It would seem hardly necessary to mention the elementary principle in optics, that the spectrum resulting from the resolution of white light is divided into three more or less distinct parts, according to wave length and effect upon matter. Beginning with the longest wave length, we have the infra red and red, or heat portion; then the yellow and green, or light (visual) portion; and finally the blue and violet, or chemical portion. Simple lenses, being of prismatic origin in manufacture, refract white light in such a way as to resolve it into its component colors, and the wave length of the red being greater, it suffers less refraction than the yellow, which in turn is refracted less than the blue; and thus the converging rays do not focus at the same point as a whole, and chromatic aberration results. Further, the fact that for any given lens there is a decrease in thickness from center to circumference, results in unequal refraction of the light as a whole and spherical aberration results, which practically means distortion of the image of an object. Both these defects, chromatic and spherical aberration, are reduced to a minimum by the combination of crown and flint glass to correct the former, and a reduction of aperture or multiplicity of lenses to overcome the latter.

It is a well-known fact, however, that the ordinary microscope objectives have what may be called residual chromatic aberration which focuses the light rays a trifle nearer the lens than the chemical rays, and thus when the image is perfectly sharp upon the ground glass of the camera, the chemical rays, which alone are active upon the photographic plate, do not accurately delineate the object. Fraunhofer has shown, that when the portion of the spectrum of greatest intensity upon the retina, that between the yellow and green is expressed by 1,000, the part between the blue and violet is only 31, so the difficulty in focusing the chemical rays is obvious. It actually amounts to focusing carefully the image, and then moving the objective toward the object an indefinite distance,

in order to obtain the desired result. Of course with low power objectives one may do this after repeated trials with some accuracy, but the chief difficulty is found in determining whether an indistinct negative is due to improper manipulation, or imperfect resolving power in the objective. For this reason, even for elementary work, such apparatus is not economical and is quite unsatisfactory.

A consideration of the apochromatic objectives of Professor Abbe and Professor Hastings, which are readily obtained with either the Zeiss or Bausch & Lomb Optical Co.'s instruments, is therefore important. These objectives having a uniform correction for spherical aberration, correct also for three colors, resulting in a better concentration of image rays and greater resolving power; this improvement in objectives brings the photographer's work nearer perfection, though there is, with high power objectives, an error which thus far remains uncorrected. This defect is balanced, however, by over-corrected eyepieces known as compensating oculars, which are designed for use with these objectives. Thus for photographic work neither an apochromatic objective with the ordinary Huyghenian eyepiece, nor the achromatic objective with compensating eyepiece is satisfactory.

The bulk of literature on photomicrography advises the use of the objective without any eyepiece; such advice is good with ordinary achromatic objectives, as the addition of the eyepiece would only introduce more absorbing and reflecting parts without correcting any of the defects in the objective. Where fine work is desired, however, and apochromats are used, the compensating ocular is not only necessary for the highest degree of correction of the system, but is useful in the regulation of magnifying power.

From the fact that so many different makes of objectives and oculars are in the market, accompanying their respective microscopes, the simplest method of rating in photographic work seems to be a statement of the number of diameters which the object is magnified. The magnifying power is most readily and accurately obtained by using a stage micrometer, one millimeter divided into hundredths, and measuring directly the magnification of the image upon the ground glass with an engine-divided steel rule.

The illumination of the object to be photographed is of so much importance that a few points may be briefly considered. An almost indispensable adjunct of the microscope in this connection is the Abbe sub-stage condenser, which not only condenses the light, but illuminates the object with a cone of light having an angular aperture equal to that of the objective employed. It is arranged to move with rack and pinion, thus providing a means for controlling the illumination to an important extent. Experience shows that the best illumination upon

the object in general obtains when the Abbe condenser is as far away from the microscopic slide on one side as is the objective on the other. Thus for oil immersion work a drop of oil must be placed between the condenser and slide as well as upon the objective. It frequently happens that when the proper position of the condenser is located for low power objectives the detail is somewhat obliterated because of too intense illumination, and the manipulation of the iris diaphragm connected with the condenser is necessary in order to obtain the best results.

From whatever source the light falls upon the Abbe condenser, an auxiliary condenser before it is advantageous, except when daylight is used upon the mirror beneath the stage. The use of daylight has disadvantages, however, which do not recommend it for photographic work. With diffused light falling upon the mirror it is impossible to use even moderately high power objectives and obtain sufficient light for focus-

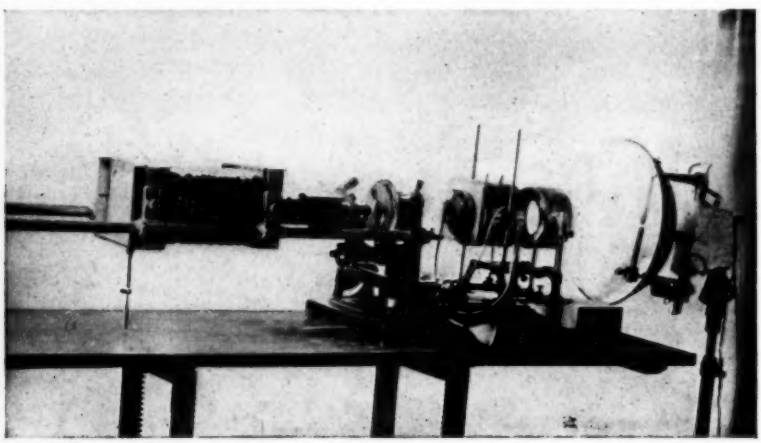


FIG. 1. CONVENIENT ARRANGEMENT OF APPARATUS FOR ORDINARY PHOTOMICROGRAPHIC WORK.

ing, while with the direct rays of the sun, unless a heliostat is used to maintain the position of the sun constant upon the mirror, one cannot obtain a photograph before the sun has changed enough to throw the image of the object off the plate. In addition to this inconvenience in general, the optical imperfections of the mirror are such as to make the production of sharp photographs difficult, and much better results are obtained with high magnifying power, by dispensing with its use and transmitting the light directly from the source through the optical system.

Photomicrographic work of low magnification has been successfully done with the various forms of artificial illuminants of low candle power. The writer, in the production of first photographs used very

successfully a series of such lights, beginning with a two-wick oil lamp behind a large Florence flask filled with water, the flask serving at once as a condenser and heat filter. Afterward, in succession, was used an argand gas lamp; a Welsbach burner; a three-wick projection lantern, burning camphorated oil; a 50-candle power incandescent lamp; and a four-burner acetylene lamp with stereopticon double condenser, to the final and most efficient light of all, an arc light which can be regulated between 1,000 and 5,000 candle power. Of course the arc light gives out a great amount of heat as well as a satisfactory quantity of light, and were the rays to fall directly upon the microscope lenses the temperature would rise high enough to endanger their mountings. To obviate this difficulty a distilled water cell two inches thick is placed in front of the stereopticon double condenser, which is directly before the arc at such a distance as to parallelize the divergent beam. It is a common idea that an alum solution is the best for absorbing heat while transmitting light. That such is not the case is proved by experiment. Melloni and others have shown that distilled water will intercept more heat rays than a solution of alum. The writer has verified that conclusion and is also able to show that distilled water transmits more light, has practically the same heat-absorbing power through a considerable range of temperature and also has the advantage of no formation of crystals in the cell. Distilled water is necessary, as with common water the air bubbles collect on the parallel faces of the cell as the temperature rises, and obstruct the passage of light.

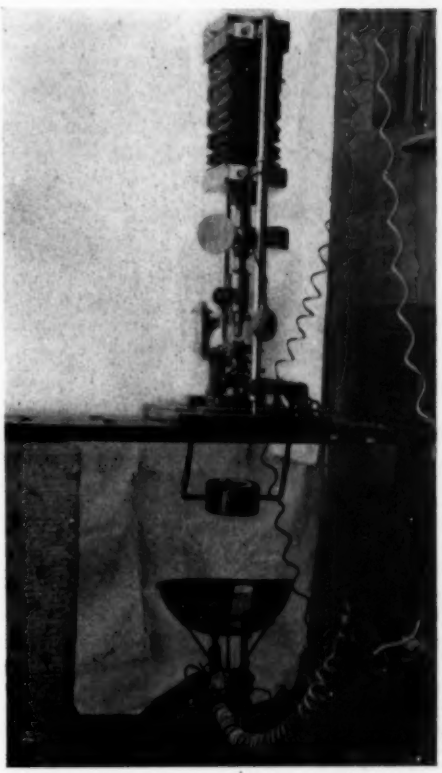


FIG. 2. APPARATUS COMPLETE FOR MAKING INSTANTANEOUS PICTURES OF LIVING MICROSCOPIC ANIMALS.

The form of apparatus shown complete in Fig. 1, using a Zeiss microscope and Bausch & Lomb adjustable camera with automatic regulating arc light, gives excellent results for ordinary dry mounted

slides that may be readily photographed with the microscope in a horizontal position. A mechanical stage is of great convenience in this work as it saves much time in accurately placing a slide, especially where high power objectives are used and when focusing must be done at arm's length. In the making of photographs of rock sections, it is frequently necessary to use Nicol prisms in order to properly differentiate particular portions. The one is placed over the ocular, or between it and the objective, and the other beneath the sub-stage condenser. As the latter is free to be rotated, it is an easy matter to bring out clearly the special features desired. Fig. 2 illustrates the apparatus in a vertical position. It must be operated in this position when freshly mounted slides are used and where photomicrographs are to be made of living organisms. A special shutter devised by the writer for the photographing of living specimens, a detailed description of which will be found in the *Scientific American* of March 24, 1900, is shown in place on the draw tube of the microscope. In place of the mirror a hole is drilled through the base of the camera stand in order to make transmitted light available. With this arrangement, as illustrated, photographs have been made in 1/50 of a second. (see Figs. 3 and 4).

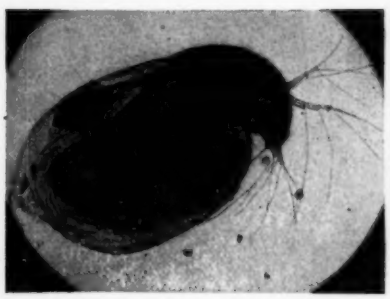


FIG. 3. PHYLLOPOD. LINE SPECIMEN. ×250. EXPOSURE $\frac{1}{50}$ SEC.

FIG. 4. DAPHINA. LINE SPECIMEN. ×150. EXPOSURE $\frac{1}{50}$ SEC.

The character of the plates used in connection with the work and a word as to their manipulation is worthy of notice, because ultimate results are not dependent upon first quality optical apparatus alone. With ordinary light and low power objectives, a slow plate is to be preferred, and with such conditions the Carbutt's B brand has given excellent results. Where polarized light is employed a color sensitive plate is preferable. Such light often gives the most beautiful colors with rock sections and crystal specimens, and the Cramer isochromatic plate renders the color values admirably.

The question of exposure must be decided principally by experience. The candle power of the illuminant; the character of the

light, whether ordinary or polarized; the kind of stain used upon the slide, if any; the magnifying power employed, and the rapidity of plate, all combine to determine the limiting values for exposure. There is scarcely opportunity in this paper to enter into discussion of these

FIG. 5. CRYSTAL OF CHLORITOID IN QUARTZ. × 110 DIAMETERS. POLARIZED LIGHT.

FIG. 6. BAND OF QUARTZ CROSSED BY MICA. ×100 DIAMETERS. POLARIZED LIGHT.

factors in detail. In general, however, it may be said that the blues transmit more actinic light than they appear to do; and so there is danger of over-exposure, while with the dark yellows and reds it is quite the reverse. Other conditions remaining the same the exposure is directly proportional to magnifying power, and since frequent changes in objectives and oculars are necessary to obtain the desired magnifica-

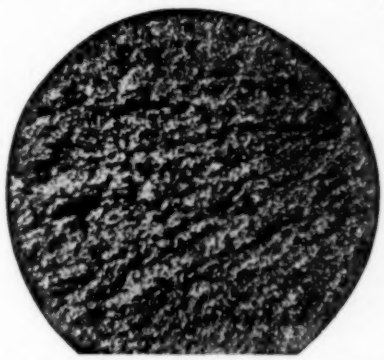


FIG. 7 SECTION OF IRON. × 60 DIAMETERS.

tion of different objects, the calculation of the exposure in terms of magnification expressed in diameters simplifies the work considerably. With living organisms that are given plenty of space to move about, in order to be photographed under conditions favorable to them, the exposure must necessarily be very short, and of course only moderately high powers can be used, and the intensity of the light must be very

high. While the subject of this article can be expected to admit of only a limited discussion of photomicrographic apparatus and its manipulation, it has seemed best to thus briefly mention a few points on the modus operandi of the work that one may the better comprehend its value.

To convey an idea of the scope of photomicrography in its application to the study and subsequent presentation of the details of objects

FIG. 8. FIG. 9.

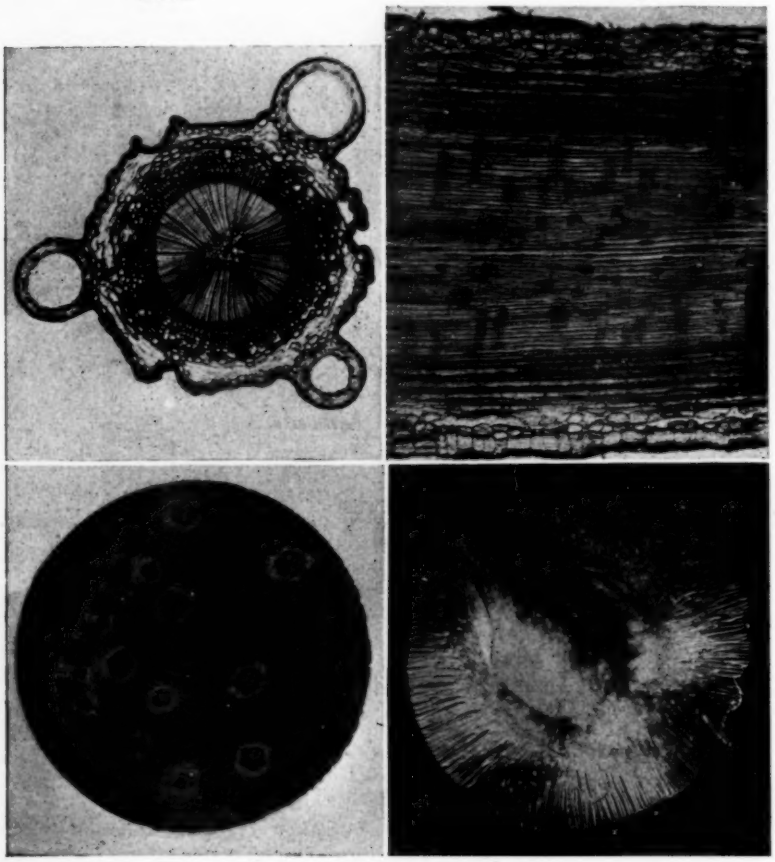


FIG. 10. FIG. 11.

FIG. 8. CROSS SECTION OF JUNIPER STEM SHOWING THREE RESIN DUCTS. × 50 DIAMETERS.
FIG. 9. LONGITUDINAL SECTION OF LINDEN. × 90 DIAMETERS.
FIG. 10. CROSS SECTION OF SUGAR CANE. × 50 DIAMETERS. POLARIZED LIGHT.
FIG. 11. WING OF SEED OF ECOREMO-CARPUS. × 80 DIAMETERS. POLARIZED LIGHT.

in nature we may well begin with the inanimate substance and finish with the living animal organism. Time was when men referred to the 'everlasting hills' as though such portions of nature were unchangeable, but modern geologic science has shown that the face of nature is ever

changing, that rocks are constantly being formed, metamorphosed and disintegrated; that the earth has undergone radical changes, and that the geography of the world in many particulars may be for one generation very different from that for the following one. Much information on the details of these changes is gained from a minute study of rocks and earth materials.

By the aid of the microscope one is able to study the fine points in the relation of different rock materials to one another, and by the aid of the camera exhibit the result to others. As an illustration of this fact Fig. 5 shows the position of a crystal of chloritoid in quartz, and Fig. 6, quartz, crossed by laminæ of mica, taken with crossed Nicols to properly differentiate the materials. These photographs are some of a number made for the Geological Survey to be used in connection with reports. The U. S. Geol. Report for 1899 on the geology of Yellowstone Park shows many photomicrographs, admirably illustrating special geologic features.

FIG. 12. COTTON FIBER INJURED IN THE PROCESS OF GINNING. × 40 DIAMETERS.

Much valuable information is also gained in this way of the structure and properties of metals both in the ore and after smelting and refining. Fig. 7 illustrates the appearance of iron whose tensile strength has been exceeded, and it is easily possible to show also differences in composition or quality of iron or steel by microscopic methods.

The photography of microscopic sections of wood aid very materially in a detailed consideration of forestry. It shows the character of the small tubes or cells of which wood is made up, indicating the definite way in which the cells of the new wood formed each year at the inner surface of the cambium layer are arranged, depending upon the climate where the tree grows. It shows the characteristic differences in cellular structure of different woods, together with the lines separating the growth of successive seasons in the trunk and bark; the medullary rays, which make the silver grain in quartered oak; and a host of other inter-

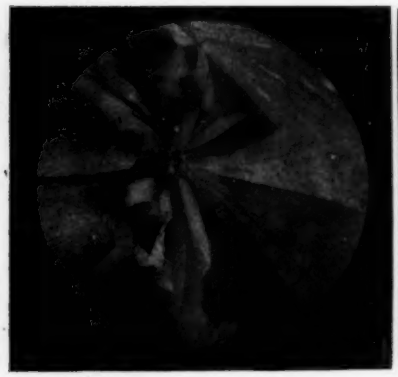


FIG. 13. PLUMOSE QUINIDINE. × 70 DIAMETERS. POLARIZED LIGHT.

FIG. 16. CINCHONIDINE. × 50 DIAMETERS. POLARIZED LIGHT.

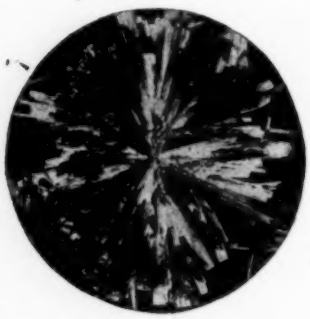


FIG. 14. PLATINO-CYANIDE OF MAGNESIA. × 70 DIAMETERS. POLARIZED LIGHT.

FIG. 17. BICHROMATE OF POTASH CRYSTALS. × 70 DIAMETERS. POLARIZED LIGHT.

FIG. 15. CRYSTAL OF $CaCO_3$ IN INDIA RUBBER PLANT. × 120 DIAMETERS.

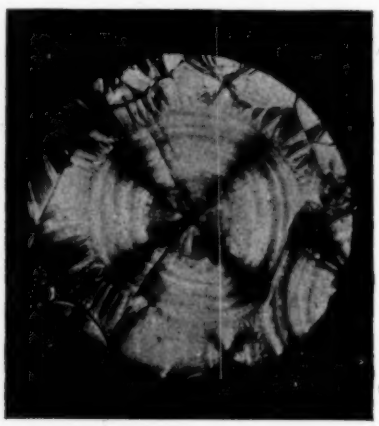


FIG. 18. BRUCINE CRYSTAL. × 70 DIAMETERS. POLARIZED LIGHT.

esting details about seeds, leaf structure, etc. It is quite possible that the microscope may yet serve to answer the present disputed question as to how the water can rise into the tops of the great trees of California, some of which are over 300 feet from the ground. It may also be mentioned that photomicrographs are of much importance in studying insects and parasites that infest and destroy forest and fruit trees. In fact, the preservation or annihilation, as seems best to serve man's purpose, of certain organisms is determined very largely by the revelations of the microscope. When such a thing as the lack of assimilating power of a leaf due to insufficient amount of light may be shown by a photograph, the far-reaching value of this science can be understood.

FIG. 19. SNOW CRYSTALS.

Its intimate connection with botany and plant structure in general is in fact so well recognized as to need little comment here. Some work in connection with cotton fibers, however, is interesting as it shows how it is possible to detect injury to the fiber in the process of ginning; such photographs in connection with others of like character, render valuable information concerning textile materials (Fig. 12).

In crystallography the photomicrograph is useful. Figs. 13–18 illustrate the appearance in polarized light of a few crystals of both organic and inorganic substances. Perhaps one of the richest of all substances in variety of form of crystals is snow. While the geometrical form is invariably hexagonal, it occurs in countless combinations and many of the crystals are very beautiful. For procuring pictures of snow crystals it seems necessary to use the apparatus in a temperature below the freezing point. The snow crystals are collected as they fall upon a surface too cold to tend to melt them, and if the work is done quickly,

excellent results are obtained. It is a singular fact that almost every snow crystal differs in some particular from all others collected. Mr. Bentley, of Nashville, Vermont, has doubtless given more attention to snow crystal photography than any one else, and the number of different forms which he has already obtained is remarkably large, and many of them are exquisite. Much has also been done on questions relative to the crystalline structure of various minerals by the aid of the microscope, as for example, 'Inclusions of Petroleum in Quartz' (*Jour. Am. Chem. Soc.*) 20: 795, and also concerning the 'Solution Vein Theory' for the origin of gold. In the same way it is possible that in the future a unanimity of opinion may be produced concerning the crystallization of iron, which is worthy of serious attention as the enormous amount of that metal used in construction increases year by year.

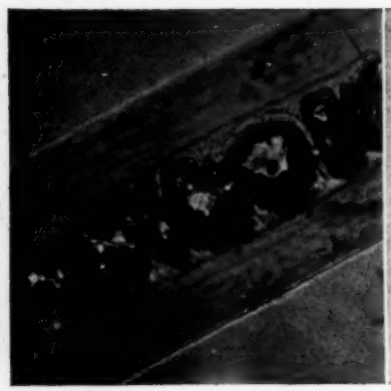


FIG. 20. COW HAIR. × 2,200 DIAMETERS.

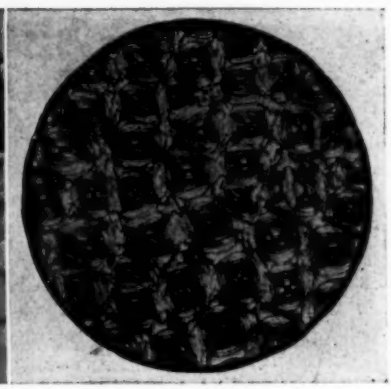


FIG. 21. CROSS SECTION OF HORN OF AFRICAN RHINOCEROS. × 60 DIAMETERS. POLARIZED LIGHT.

The value of the part which the microscope plays in determining facts about the minute structure of the animal organisms can scarcely be overestimated. The bacteriological analysis of water in connection with zymotic diseases; the determination of disease germs in impure air; the examination of useful and injurious bacteria in food; all this and more must be credited to the microscope in the development of medical science and sanitation.

A detailed description of all the applications of photomicrography to nature study can not well be given here, and so a few of the important ones only have been briefly noticed. The chief value of it all seems to be the aid rendered in the dissemination of knowledge. To attempt to look beneath the superficial and discover the ulterior is a fundamental desire in the active, civilized mind. Since the beginning of the seventeenth century, when Galileo was imprisoned for stating his belief in the motion of the earth, we look with pride at the development of science

through the minds of such men as Newton, Kepler, Lyell, Huxley, Ohm, Faraday, Joule, Helmholtz, Le Conte, Darwin and scores of their contemporaries.

The beginning of the twentieth century finds the major part of the civilized world bound to recognize the power of scientific thought and investigation in its bearing upon the prosperity of nations, and the equality of man. More and more attention is wisely being given to methods of teaching in our primary and secondary schools as well as to college and university work. Such attention is even now beginning to manifest its results, as we note men having completed their university training for the Doctor's degree under twenty-five years of age. No doubt it may truly be said that such men are brilliant, or have

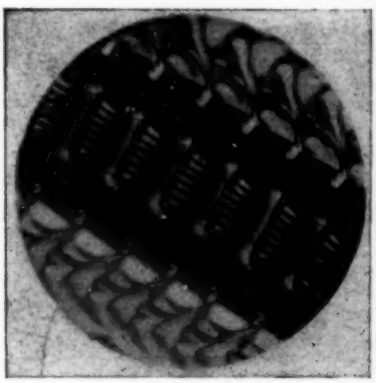


FIG. 22. PALATE OF A WHELK. × 90 DIAMETERS. POLARIZED LIGHT.

FIG. 23. PROBOSCIS OF FLY. × 80 DIAMETERS.

exceptional advantages or both combined for the result attained, yet the fact remains that elementary knowledge gained from secondary instruction molds to a great extent the future of the individual. This phase of study is all the more important since it is beyond the control of the pupil. Beyond his control, for though volumes may be written, and instructors may be at hand, the average student does not early in life appreciate the necessity or value of application to study.

Interest in a subject is the prime factor in its mastery, and the *method* of presenting the subject will tend either to stimulate or allay the interest of the pupil.

The time devoted to the study of a subject in the secondary school is frequently very limited, and the teacher may profitably consider the needs of the pupils and seek to originate such methods as will accomplish the most for the time allotted. One important saving of time in the class room, both for elementary and advanced work along most scientific lines, is the use of pictures in making certain points clearly understood, and

it seems that either the stereopticon, or wall pictures large enough to be seen by the class as a whole, are most desirable. The instructor may thus explain to a class in a few minutes what would under other conditions require hours to make clear to them. This mode of procedure is as useful with pictures of the infinitesimal organisms and material in nature as with views of miles of landscape concerned with the geography of the globe.

Take for example the little daphina, shown in Fig. 4, magnified 150 diameters. This when thrown from a slide on an eight-foot screen makes the original magnified to nearly six thousand diameters. A class of students may look first at a tiny speck in a glass of clear water, which is perhaps one third the size of a pin-head, apparently without definite form, and of no consequence, but which, when seen enlarged, is shown to possess all the organs of a living animal. And further to illustrate how very tiny a particle of matter may become and yet be a *mass* as distinguished from molecules and atoms, the student has only to note such an illustration; for he sees that this microscopic animal is a mass as truly as is the elephant. In the study of rocks, of plants, of animals, even in a most elementary way, some very instructive lessons concerning their minute structure and how it concerns their outward forms and functions may be learned by such pictures.

Of course, all schools are not so situated as to be able to use a lantern in this way, though many have felt the importance of its use and of making a place for it. With the cheap forms of apparatus on the market at present and the readiness with which electricity or acetylene gas is obtained for an illuminant, the lantern should find its proper place in the class-room. Various forms of apparatus are also accessible for the projection of the microscopic slides directly, but in general, they give more trouble in handling to the average person than they are worth. The lantern slide is infinitely more satisfactory for general illustrative teaching. Another and in some cases better method for illustrating a subject is by the use of large pictures which can be hung up before a class and readily explained. Where classes are not too large, a photograph 20″ x 24″ in size is large enough, and there is then no necessity for a darkened room as with the lantern, and the picture may be considered in just the proper place in the course of a talk on the subject. These pictures are simple enlargements on bromide or velox paper from the original microscopic negative and cost but little more than lantern slides.

Since the scientific knowledge structure is continually building upon the foundation of accepted results of earlier investigators, it may be said in conclusion that photomicrography serves a double purpose. First, it enables the scientific investigator to determine accurately a knowledge of the minute physical structure of matter, and secondly, it provides a means of placing such information before others in a comprehensive manner.

SUGAR AND THE SUGAR BEET.

By JOHN WADDELL, D.Sc., Ph.D.
SCHOOL OF MINING, KINGSTON, ONTARIO.

THE total production of sugar in the world is between seven and eight million tons yearly; in 1898–99 it was 7,839,000 tons. Of this amount about three eighths is obtained from sugar cane and five eighths from beets.

The United States in 1898 consumed 2,047,444 tons of sugar, each ton being 2,240 pounds. This was an average of sixty-one pounds for every man, woman and child in the country. In 1897 the consumption was nearly sixty-four pounds per head, and this figure is approximately the average for the last ten years, the average for the preceding decade being ten or twelve pounds less.

The United States consumes much more sugar per head than is consumed in Europe. In 1895, when the consumption in the United States was 62.60 pounds per capita, the consumption in Europe was 25.64 pounds per capita. The consumption in nearly all the countries of Europe is very low, and the average would be very much lower if England were left out of account. In England it is far in advance even of that of the United States, being 86.09 pounds in 1894–95, when Denmark, which in Europe stands next to England, consumed 44.66 pounds, that is, only slightly more than half as much. The great consumption in England is largely due to the amount of jams and confectionery manufactured, much of which is exported. Germany exports large quantities of sugar to England and imports confectionery. This is due to the special bounty arrangements in Germany. The government does not bonus the production of sugar, but taxes it. It however gives a rebate on the sugar exported, in such a way as to constitute a bounty. An excise duty is placed upon beets used in the manufacture of sugar. On any sugar exported a drawback is allowed. The law passed in 1869 assumed that beets contain eight per cent. of sugar, so that the manufacturer would get as much drawback from the government if he exported eight tons of sugar as he had paid on one hundred tons of beets. But owing, on the one hand, to improved cultivation of the beet, and, on the other hand, to improved methods of extraction, instead of twelve and one half tons of beets being necessary for the production of one ton of sugar, less than eleven tons were required in 1877, and in 1898 only seven tons. Now, therefore, the German manu-

facturer obtains fourteen instead of eight tons of sugar from one hundred tons of beets, and if he exports the whole amount receives a drawback of fourteen dollars from the government for every eight dollars he has paid into the treasury; in other words, he has a bounty on six tons out of fourteen. This has so far encouraged the manufacture of sugar in Germany that it increased from 378,000 tons in 1878 to 1,755,000 in 1898, or over 400 per cent.

England exports so much of the sugar that is tabulated as consumed that it is probable that the average actually eaten by each person in the United States is greater than in any other country. Each person uses about $2.50 worth of sugar each year, making for the whole country approximately two hundred million dollars' worth. About half this amount of money is now sent to foreign countries for the sugar we import; for while we refine most of our sugar ourselves, we manufacture only an eighth of it.

Of the sugar consumed in the United States, three quarters is provided by the sugar cane, the remainder being manufactured from beets. There is little likelihood of much growth in the manufacture of domestic cane sugar, though at present there is more cane sugar made than beet sugar. In 1899, 160,400 tons of cane sugar were manufactured, as opposed to 79,368 tons of beet sugar. But the cane sugar industry is of long standing, while in 1888 the quantity of beet sugar manufactured was only a thousand tons.

Germany not only was the pioneer in the manufacture of beet sugar, but she has easily held the first place, except for a few years in the early part of last century when France took the lead. In 1747 Margraf showed in a paper, read before the Berlin Academy of Sciences, that he had been able by means of alcohol to extract 4.5 per cent. of sugar from red beet and 6.2 per cent. from white beet. The manufacture was not, however, begun on a commercial scale. Extraction by alcohol was expensive, and comparatively cheap sugar came in from the British colonies. It was not until 1799 that the first beet sugar factory was established by Achard, director of the Royal Prussian Academy of Sciences, and the beet sugar industry is therefore little more than a century old. Even by Achard's process, the cost of making beet sugar was greater than its value in the market; but in 1811 Napoleon blockaded the European ports and prevented the entrance of colonial sugar. This enormously raised the price of cane sugar, which cost in 1811 between one and two dollars a pound, though in 1805 five or six pounds could be bought for the same money. After Napoleon's downfall, the former state of affairs returned, but, in the meantime, the beet sugar industry had been stimulated and methods had been improved. In France political enmity towards England prevented the inroad of colonial sugar to the same extent as in the rest of Europe, and up till

1836, or thereabouts, France was the leading producer of beet sugar. Though Margraf had been able on a small scale by using alcohol to obtain from four to six per cent. of sugar, at first only two or three per cent. was extracted by the factory processes, but owing to improvements introduced in its manufacture as well as to the cultivation of beets with greater sugar content, five or six per cent. of sugar was obtained in the early thirties.

Schatten's invention of a saccharometer for estimating the amount of sugar in beets, and of several very important processes, revived the industry in Germany and placed that country in the van, which position it has held ever since. The growth of late years is shown by the fact that whereas in 1877–78 4,090,968 tons of beets passed through the factories, in 1898–99 the amount was 12,144,291 tons or 2.97 times as much. The amount of raw sugar produced in the same time increased from 378,009 tons to 1,710,000 tons or 4.52 times as much. It will be noticed that the increase in sugar produced is much more than the increase in beets treated. This is because of the greater amount of sugar extracted. Whereas in 1877, one ton of sugar required 10.82 tons of beets, in 1899 one ton of sugar required only 7.01 tons of beets. In other words, in 1899 three tons of sugar were made from the same weight of beets as in 1877 yielded but two tons.

Hardly had France and Germany succeeded in establishing the beet sugar industry before the United States made some experiments in the same direction. In 1840 a factory was located in Connecticut. It did not prove successful. Later other efforts were made, but with no better success. Among the causes of failure were careless methods of beet culture and very inadequate methods in the factory. It was even thought by many that simple apparatus, like that used in making maple sugar, was sufficient; moreover, the early factories were located in places that were not suitable. The first factory that had any appreciable success was at Alvarado in California. It was built in 1870; the company failed in 1876, but was reorganized in 1879, and the factory has been in operation ever since.

The Department of Agriculture under the federal government for a number of years carried on investigations and published reports and reviews, but its work was suspended in 1893. In 1897, however, it was resumed with renewed and increased vigor, and since then the government has taken great interest in the matter. It has distributed seed in a large number if not all the states and has sent out instructions to farmers who accepted seed for experiment. The Department of Chemistry has made analyses of thousands of samples of beets, and investigations have been made upon the influences of soil, temperature, rainfall and other conditions upon the growth of the beet, its sugar content and the purity of the sugar. In 1898 over twenty thousand

pounds of seed were sent out to experiment stations for distribution. The value of the government's work is shown by the rapid strides with which the industry has advanced. In 1897 there were nine factories in operation in the United States, of which four were in California. In 1900 there were thirty-six, ten of them being in Michigan, which three years earlier had none. Germany has four hundred factories and turns out an average of between four thousand and four thousand five hundred tons of sugar for each factory. The average increase per annum in the consumption of sugar in the United States between 1881 and 1899 was over sixty thousand tons. In order to meet this increase alone, fifteen factories would need to be added each year. It is thus evident that though the industry has grown so markedly, the *increase* in consumption is not provided for. Nearly five hundred factories would be required for our present needs, and, after those were provided, ten or fifteen should be added each year to provide for growth, if the increase in consumption keeps up at the rate of the last twenty years.

As has been stated, one of the causes of the early failure of the beet sugar industry in this country was the location of factories in unsuitable places, and one of the most important features of the government's work of late years has been the investigation of the places where beets can be grown profitably. Beets should have a sugar content of at least 12 per cent. and perhaps even 13 per cent. or 14 per cent., otherwise it will not probably pay to erect a factory. This is not because at present prices a factory using beets of 12 per cent. sugar could not pay, but because in many parts of the country a considerably higher percentage is obtainable, and, in view of competition, the most favorable locations should be chosen. In the examination made by the Department of Agriculture of beets sent in during the year 1897, '98 and '99 from thirty-nine states and territories, it appeared that Arkansas was least suited for beet culture, giving an average of a little over seven per cent. of sugar. On the other hand, Nevada showed an average of eighteen per cent. of sugar in the samples examined.

A matter which is almost, if not quite, as important as the percentage of sugar is its purity and in this respect Nevada was almost at the top of the list, the 'coefficient of purity' being 83.8. The coefficient of purity means the percentage of sugar in the total solids dissolved in the juice. For example, if one hundred pounds of beets yield a juice containing fifteen pounds of solid matter dissolved in it, twelve pounds of which is sugar and the remaining three something else, the sugar content is said to be 12 per cent. with a coefficient of purity 80. Impurity keeps part of the sugar from crystallizing and so prevents its recovery in the factory and hence a high coefficient of purity is exceedingly important.

A very important factor in the cultivation of beets is the tempera-

ture. A large part of the United States has too high a temperature. Where the temperature is high beets grow luxuriantly, but they contain a small percentage of sugar. On the other hand, where frosts come early in the autumn, the beets can not arrive at maturity. Other things being equal, the farther north the beets can grow to maturity the greater will be the sugar content. In 1897 the Department of Agriculture gave as a provisional area a zone having a mean temperature between 69° F. and 71° F. for the months of June, July and August. This forms a strip across the country sometimes very narrow, sometimes quite wide —in New Mexico and California running south of the thirty-third parallel of latitude, in Dakota north of the forty-sixth, forming on the map a serpentine band which, owing to its many folds and twistings, has a length considerably greater than double the width of the continent. In addition to this belt there are a few outlying areas as for instance a portion of Washington. The belt begins on the east in the neighborhood of New York City, and on the Pacific it forms a long strip stretching between four and five hundred miles, almost due north and south, and extending to the Mexican boundary. Later investigation has widened this area a little, chiefly on the north, but has not very materially affected it. It must not be supposed that all parts of the belt are equally favorable. For instance, though North Dakota and southern California have the same average temperature in June, July and August, in the former place frosts come very early and the winters are severe, while in the latter there is little frost at any season.

The rainfall is a matter of importance. Warm rains in the early part of the season and dry weather during the period of maturing are best. In arid districts, irrigation may be resorted to, and has the great advantage that the supply of moisture can be regulated. Irrigation works are usually expensive and do not ordinarily pay in the raising of cereals, but the sugar beet is a valuable crop and experiments already made point to the probability that Colorado, Utah, New Mexico and other similar states will become extensive producers of sugar beets. Ten million acres of arid land could be irrigated comparatively easily and that would more than supply the world with sugar.

The growth of the sugar industry in Michigan is very interesting. In northern Michigan lumbering has been carried on very extensively for a number of years. The result is that the timber areas have been rapidly denuded. The question as to the use to be made of the land from which timber was removed became pressing. The soil was considered too sandy for ordinary agricultural purposes but it turns out to be very suitable for beet culture and sawmills are being replaced by sugar factories.

The sugar is not the only valuable part of the beet. When the juice

is extracted there is a pulpy residue from which the liquid is pressed out. This pulp is very valuable as food for stock. Some factories have dairies in connection with them. The experiments already made have been very satisfactory. The pulp is probably the cheapest food that can be used considering the amount of nutrition. The leaves are also valuable as food, but probably still more valuable as a fertilizer. Sugar takes nothing from the ground. It is made from the water vapor and carbon dioxide of the air. But the tissue of the beet contains considerable potash, magnesia, phosphoric acid and nitrogen, and all these are removed to a greater extent by the leaves than by the roots. If then the leaves are left on the ground or are plowed under, the soil is much less exhausted than if they are taken away. For beet-raising the cultivation of the soil must be very carefully attended to. This cultivation has a very beneficial effect on other crops grown in rotation with the beet, hence the advantages of beet-growing are indirect as well as direct.

The cost of raising beets is considerable, but, on the other hand, the returns are large, and the profits may be estimated as on the average twenty dollars an acre.

PETER GUTHRIE TAIT.

By C. K. EDMUNDS,
JOHNS HOPKINS UNIVERSITY.

NEXT to Lord Kelvin, perhaps the most notable figure among the physicists of Great Britain during the past forty years has been Peter Guthrie Tait, professor of natural philosophy in the University of Edinburgh since 1860. One of the first to establish laboratory instruction in Great Britain, and beginning his career at a time when the now prevalent ideas of energy were yet unborn, he has had much to do with the shaping of scientific thought and education during the latter half of the nineteenth century.

He was born at Dalkeith (a town of several thousand inhabitants, about six miles southeast of Edinburgh) in 1831. His early education was obtained at the Dalkeith Grammar School and at the Circus Place School in Edinburgh. Tait was a distinguished pupil, and those of his schoolfellows who are still alive speak of him with so much love and respect that he must have been a leader among them. Clerk Maxwell was his most intimate school and college friend, and the friendship thus begun continued till Maxwell's death, undisturbed by the fact that they were rivals for the Edinburgh chair in 1860. 'Both were men of playful disposition and of absolute frankness and sincerity.'

Tait studied at Edinburgh University for one session under Kelland and Forbes, and the promise he then gave was amply fulfilled at St. Peter's College, Cambridge, where he became senior wrangler and first Smith's Prizeman in 1852, being just twenty-one years of age. His private tutor was William Hopkins, to whose tuition Tait attributed much of his mathematical skill. Tait seems to have joined heartily in all phases of undergraduate life at Peterhouse. He was a keen golfer, and for forty years he spent an annual holiday on the links at St. Andrew's. It is said that his son's progress to the championship in golf was dearer to him than his own scientific fame. And some declare that the untimely death of his son, an officer in the Black Watch in the South African War, hastened his father's last illness, to which he succumbed on July 4, 1901, at seventy years of age.

In 1854 Tait was appointed professor of mathematics in Queen's College, Belfast, and became acquainted with Andrews, the chemist, and Rowan Hamilton, the mathematician. Andrews stimulated his love for physical research and helped him to gain the power of apprehending the facts and of plainly formulating the theories of natural philos-

ophy. Through the works and the personal influence of Hamilton he was led to the study of quaternions, to which he gave much attention.

In 1860 he was elected to the chair of natural philosophy in Edinburgh, resigning it in February, 1901, on account of a lingering illness, which resulted in his death four months later. It is estimated that about ten thousand students passed through his class-room during those forty years, and few could do so without carrying away some impress from this notable teacher. Among the first of his 'researchers' were a remarkable trio—Robert Louis Stevenson, Wm. Robertson Smith, the distinguished Scottish Biblical scholar and orientalist, and Sir John Murray, the well-known publisher. Great must have been the attraction of Tait's personality to bring together three men so highly distinguished, yet so utterly different.

About the time of his appointment to the Edinburgh chair, Tait became acquainted personally with Lord Kelvin, who, though also a Peterhouse man, had left Cambridge before Tait came up, "and was already independently and in conjunction with Joule, and concurrently with Rankine and Clausius, writing his classical memoirs on the theory of energy. The first edition of Tait and Steele's 'Dynamics of a Particle,' published in 1856, does not contain either of the words *work* or *energy*. In its original form it was founded on Pratt's 'Mechanical Philosophy,' and written on the old-fashioned Cambridge lines, which knew not of Lagrange and Hamilton. Six years later it is on record that in his introductory lecture Tait handled the notions of the *energetic* school with freedom and laid down the foundations of a thoroughly modern course in physics. Probably, therefore, he had come under the influence of Joule and Kelvin before he met the latter personally." The conjunction with Kelvin produced the famous treatise on 'Natural Philosophy' by Thomson and Tait in 1867, which began a new era in mathematical physics. Dozens of men nourished by the strong meat of its pages have written treatises in continuation of the lines there laid down.

Tait's contributions to text-book literature include, besides the two works just mentioned, 'Elements of Quaternions,' 1867; 'Introduction to Quaternions' by Kelland and Tait, 1868; 'Recent Advances in Physical Science,' 1876; 'Thermodynamics,' 1868; 'Light,' 'Heat,' 1884; 'Properties of Matter,' 1885 (revised to 1899), and 'Dynamics,' 1895.

Although Tait rarely spoke on religious topics, and in general avoided theological controversy, his friends were aware that he held decided views on such matters. He was the joint author with Balfour Stewart of the 'Unseen Universe' (first printed privately in 1875), a book showing, to use Tait's own words, how baseless is the common belief that science is incompatible with religion. "It calls attention

to the simple fact, ignored by too many professed instructors of the public, that human science has its limits, and that there are realities with which it is altogether incompetent to deal."

Tait's collected scientific memoirs have been published by the Pitt Press, and embrace between one hundred and two hundred papers relating to a great variety of subjects. It would be out of place in this paper to attempt any detailed examination of these articles. A rapid sketch of the contents of the two volumes already published will however be given.

A large proportion of each volume is given up to quaternion investigations, a subject and method in which Tait remains almost the sole authority. Lord Kelvin has given the following reminiscence of the collaboration in 'Natural Philosophy': "We had a thirty-eight years' war over quaternions. He (Tait) had been captivated by the originality and extraordinary beauty of Hamilton's genius in this respect, and had accepted, I believe, definitely from Hamilton to take charge of quaternions after his death, which he has most loyally executed. Times without number I offered to let quaternions into Thomson and Tait, if he could only show that in any case our work would be helped by their use. You will see that from beginning to end they were never introduced." In a note in his second volume Tait states that Klein's account of quaternions rests on a misapprehension; and remembering that, though 'the grandest characteristic of quaternions is their transparent intelligibility,' men like Cayley and Klein have gone astray, we may be excused from any attempted discussion of them here. Other abstruse papers are those on 'Amphicherial Knots,' and 'Knottedness.' Many addresses and notes of a less technical nature serve, as Lord Rayleigh has remarked concerning his own, 'to relieve the general severity.' Here and there a biographical notice as of Listing, Kirchhoff, Sir Wm. R. Hamilton and Rankine, or the reprint of an encyclopedian article, as on 'Mirage,' 'Force,' etc., gives interest to the miscellany. Tait was a party—and an active party—to many polemical discussions, but very properly all traces of these keen controversies are omitted in his collected papers.

We have yet to notice the best of his researches. The most noteworthy theoretical discussions are those on the kinetic theory of gases (five papers, *Trans. Edin. Roy. Soc.*, 1886-92), on impact (three papers, 1888–92), and on the path of a rotating spherical projectile. These latter were due to his interest in golf, and on this subject he wrote a series of popular articles, which it is said were widely read and appreciated.

His most important theoretical paper is the review of the kinetic theory of gases, in which he analyzed into their logically simplest elements, the first principles of a difficult subject. He gave several new

view-points from which to examine the foundations of the theory. There are three advances in the details of the theory with which his name is generally mentioned, as follows: (1) He showed that the analogy between the coefficient of diffusion for gases and the conductivity for the propagation of heat can not be pushed to the conclusion that since the conductivity is a constant magnitude, the coefficient of diffusion is a constant also, for experiments with the same pair of gases. Tait showed that this expectation is not justified by the formula in terms of which the coefficient is deduced, showing in fact that it depends at any instant not only on the temperature and on the pressure of the mixture, but also on the ratio in which the two gases have mixed with each other by that time. (2) He showed that in applying Maxwell's law of the distribution of velocities (a law deduced for a gas without total progressive or rotational motion) to the case of a gas the body of which is in rotation, the interval of time within which the mechanical theorems (deduced for the static conditions) remain valid with sufficient exactness for a single layer (the whole body of gas being considered as divided into layers between which the interchange of energy is slow) may be long enough to allow the very rapidly resulting arrangment in the distribution of velocities according to Maxwell's law to occur. In each of these layers, then, Maxwell's law holds good for the distribution of velocities on the condition that the velocity in which a particle shares by the flow or rotation of its layer is to be subtracted from the value which it would have in the state of rest and equilibrium of the gas as a whole. (3) The calculation of the coefficient of viscosity on the assumption of Maxwell's law of distribution of velocities.

In reading Tait's papers on the kinetic theory of gases it is interesting to note the author's frank confession: "I have abstained from reading the details of any investigation (be its author who he may) which seemed to me to be unnecessarily complex. Such a course has, inevitably, certain disadvantages, but its manifest advantages far outweigh them!"

Tait's chief experimental research was that on the compressibility of water, undertaken in connection with an investigation of the errors of the deep-sea thermometers used on the famous voyage of the *Challenger*. It is an interesting record of a laborious investigation undertaken to decide a very important practical question.

Several earlier investigators had studied the compressibility of liquids, always chiefly of water. Only the chief among them need be mentioned here. Canton, a hundred and twenty-six years before, had not only exhibited the compressibility of water, but had shown that it decreases as the temperature is raised; and Perkins in 1826 showed very clearly that in water at 10°C. the compressibility diminishes as the pressure increases, quickly at first, afterwards more and more slowly;

but Perkins' estimates of pressure are inaccurate, and no numerical data of any value can be obtained from his results. Regnault in 1847 attempted to take into account the compressibility of the piezometer by applying pressure alternately to the outside and the inside of the piezometer, and then simultaneously to both. But this method gives the elastic constants of the piezometer only when dealing with an absolutely incompressible liquid. Amaury and Deschamps measured the change in external volume of the piezometer, but Tait points out that unless the bulbs are truly spherical or cylindrical, of uniform thickness and homogeneous material, errors due to application of pressure on the outside or inside alone may be introduced of the same order as the quantity to be measured. A very complete series of measurements had been made for water from 0°—100°C. by the two Italian experimenters, Pagialini and Vincentini, but only for low pressures. Moreover, though they made careful determinations of the change in the glass due to changes of temperature, they failed to eliminate the effect of pressure on the piezometers, applying pressure to the inside only, and so their results are some forty per cent. too great. Lastly, Amagat made very extensive experiments up to 3,000 atmospheres, but he considered the compressibility of the glass to be of small effect and consequently left it out of account, and the first really satisfactory work on this important subject was that accomplished by Tait and his assistants, the full report of which appears in the 'Challenger Reports.'*

The great merit of Tait's work was the careful determination of the pressures used, and the preliminary researches on the compressibility of mercury and of glass, so as to apply the proper corrections to his thermometers and piezometers, together with the fact that his investigations extended to sea-water and to solutions of salt of various strengths. A brief summary of his most important results follows:

As an approximation for the compressibility of fresh water through the whole range of the experiments (pressure from 150 to 450 atmospheres and temperatures from 0° to 15°C.), he secured the formula:

$$\frac{0.00186}{36+p}\left(1-\frac{3t}{400}+\frac{t^2}{10,000}\right)$$

where t is the temperature of the water in degrees centigrade and p is the pressure in tons per square inch.

The point of minimum compressibility of fresh water is about 60°C. at atmospheric pressure, but is lowered by increase of pressure.

The average compressibility of sea-water is about .92 of that of fresh water, with a minimum compressibility at about 56°C., lowered by increase of pressure.

The average compressibility of salt solutions for the first p tons of additional pressure beyond atmospheric pressure is, at 0°C.—

$$\frac{0.00186}{36+p+s}$$

* Vol. II., 'Physics and Chemistry,' London, 1889.

where s parts of salt are dissolved in 100 of water, s varying in Tait's experiments from 0 to 21.4.

Six miles of sea water, at 10°C. throughout, are reduced in depth 620 feet by compression. Hence the pressure at a depth of six miles is nearly 1,000 atmospheres.

The maximum density-point of water is lowered about 3°C. by 150 atmospheres of additional pressure.

The maximum density-point coincides with the freezing-point at —2°.4 C., under a pressure of 2.14 tons.

As to the proper correction to apply to the *Challenger* thermometers, Tait showed that that previously given by Davis, viz.: .5°F. per ton per square inch, was greatly too large, and that of five sources of error which entered into the test experiments, only one held for the circumstances under which the *Challenger* thermometers were actually used, that the other four were proper for the experiments in the laboratory, but not for sea-soundings. The only cause of error active in the case of sea-soundings was the direct effect of pressure on the glass and mercury of the thermometer, and the correction due to this was but 0°.14 C. for every mile of depth.

Next to his work on the compressibility of water and the allied investigations, come Tait's experiments in thermo-electricity. He made two contributions in this field.

1. Having supposed that the Thomson effect (the absorption or liberation of heat-energy in a conductor whose temperature varies from point to point when traversed by a current of electricity, the effect being reversible, in any given conductor, with the direction of the current) might, like thermal and electrical resistance, be directly proportional to the absolute temperature, he verified his assumption by experiment, finding that the curves for the e. m. f. in terms of absolute temperature for junctions of any two of iron, cadmium, zinc, copper, silver, gold, lead and some others are parabolas with their axes vertical, if the e. m. f. be taken as ordinates, the apex corresponding to the neutral point, or point of reversal. This amounts to showing that the curve representing the thermo-electric power* of any couple in terms of the mean temperature of its junctions is a straight line. We need only draw the diagrams of the thermo-electric powers of all the metals taken separately with one of their number in order to learn the values of the thermo-electric powers of all the metals taken in pairs in any combination. Lead was adopted as the metal of comparison, because as Le Roux had shown, its specific heat of electricity is zero.

By the 'specific-heat of electricity' is meant the amount of heat-energy developed in the given conductor, according to the Thomson

* The 'thermo-electric power' of a couple for a given temperature is the e. m. f. between its junctions when they are kept respectively ½° above and ½° below that temperature.

effect, between two points whose difference in temperature is 1°C., when a unit quantity of electricity passes between them. And Tait's work amounted to showing experimentally that the 'specific heat of electricity,' as defined by Kelvin, was for any given substance directly proportional to the absolute temperature. This is sometimes spoken of as Tait's Law.

From these experimental results Tait suggested the well-known form of the thermo-electric diagrams, the rough preliminary suggestions for which Lord Kelvin had already given. Under Tait's development the diagrams exhibit not merely the relative thermo-electric positions of the metals at various temperatures, with their neutral points, but also the specific heat of electricity in each metal in terms of temperature, the amount of the Peltier effect, and the e. m. f. (and its direction) for a circuit of any two metals with given temperatures of the junctions.*

2. Tait also discovered a multiplicity of neutral points for thermo-electric couples of certain substances, such as circuits of iron coupled with various alloys of platinum with iridium, nickel and copper. In each of these cases there are at least two neutral points below the temperature of white heat, and others at still higher temperatures.

Professor Chrystal gives† the following vivid picture of Tait:

> Ready to take a blow, he did not always spare his strength in giving one, and his opponents did not always relish his rough play. It may be doubted whether many of them carried for long any resulting bitterness; but undoubtedly some of them were led, temporarily at least, greatly to mistake his character. Personal contact with him at once dissipated any such misconception. To feel the magic of his personality to the full it was necessary to visit him in the little room at the back of his house, the Spartan simplicity of whose plain deal furniture and book-shelves, unpainted, unvarnished, ink-spotted, littered with books and pamphlets and with piles of manuscript bristling with quaternion symbols, was finely in tune with the tall, rugged figure, the loud, hearty greeting and the radiant, welcoming smile of the kindly host. Ten minutes in that sanctum would have made a friend of the bitterest foe. Thither at various times came Joule, Andrews, Kelvin, Stokes, Helmholtz, Rankine, Clerk Maxwell, Balfour Stewart, Rowland, the Wiedemanns (father and son), Adams, Newcomb, Huggins, Newton, Lockyer, Hamilton (at least in spirit), Cayley, Sylvester, Hermite, Cremona, Clifford, Klein, Bierens de Haan and many more, the majority, alas, now departed like their common friend."

---

* For a discussion of these diagrams see J. J. Thomson's *Elec. and Mag.*, pp. 499–505.

† *Nature*, July 25, 1901.

CONCERNING THE AMERICAN UNIVERSITY.*

By Professor J. McKEEN CATTELL,
COLUMBIA UNIVERSITY.

POLITICAL, social and educational institutions rise and decline, as species and genera have come and gone in the history of organic life. Evolution has been on the whole progressive, leading to greater differentiation and more complex interdependence. But there have been strange creatures—suited perhaps to their environment, but monsters from our point of view—brutes encased in impenetrable armor and dragons undecided as to whether they should crawl or fly. Our universities have developed in the main by the crude and wasteful methods of natural selection; but a new factor in evolution has in these latter days become possible and perhaps even potent. The struggle for existence, prodigal of time and careless of the individual, resulted in the production of animals that could learn by experience, and finally in such as can consciously look before and after and plan for what is not. Hitherto human foresight and reason have had but little to do in the selection and direction of educational methods, but the time has come when we can at least form opinions and judgments. We realize that certain surviving dinosaurs should be exterminated, that certain fads spread like weeds, that the 'fittest' is not always the best. Our reason is as yet only a toy in the hands of a child, but as the child grows the toy may become an engine competent to direct our civilization. We have not at present a science of education or an art of education based on science, but we are beginning to have ideas. However vague and immature these may be, it is well that they begin to exist, for thanks to the contagion and possible immortality of ideas, natural selection can here work more rapidly than in the case of organisms. It may take a million years to mold a new whorl on a shell, whereas the entire system of higher education in America has developed since the Johns Hopkins University opened its doors twenty-five years ago.

The outline history of the American university is a familiar story. We had the English college, beginning with Harvard in 1636, for the training of the clergy and as a denominational school. With many

* An address read before the members of Phi Beta Kappa of the Johns Hopkins University on May 2, 1902.

sects colleges multiplied like churches in a village, supported, so far as they were supported, by religious zeal. Free education has been fostered by our states as never before, and where the field was clear, beginning with Michigan in 1837, state universities became the head of the public school system. Technological schools and departments —beginning with the Rensselaer Polytechnic Institute in 1824—were founded in answer to the needs of a country requiring material development. Independent or quasi-independent schools of divinity, medicine and law gave the inadequate preparation that the pressing demand for clergymen, physicians and lawyers allowed. University work did not exist, and our B.A.'s swarmed to Germany, where ideals of research and creative scholarship had arisen, which took kindly to transplantation and an unexhausted soil. Certain native agencies, the Smithsonian Institution, the scientific academies, the geological surveys and the like, modestly furthered research and contributed to the university ideal.

In a general way the old Cambridge college, adjusting itself to the practical needs of a democratic and industrial country, adding the German faculty of philosophy, and gathering in the professional schools, has given us our American university. These three elements, represented by the bachelor's degree, the doctorate of philosophy and the professional degrees, are variously combined and developed in our different institutions; and this certainly gives great flexibility and possibilities to university development. The foundation of new universities—Cornell, Johns Hopkins, Stanford and Chicago—and the enlargement of the resources of private and state institutions have greatly favored progress and differentiation. We have no one kind of university, but many types, each seeking to work out its own salvation. Here surely is ground for hoping that we shall soon set educational models.

But twenty-five years is a short period, and it would be no cause for surprise if it has given us more problems than solutions. The college, originally for secondary education, but with higher education attached, is in a state of unstable equilibrium. The distinction between courses for culture, courses for higher specialized liberal training and courses fitting for the professions appears to have a historical explanation rather than a logical justification. Every student during all his course of education—namely, from the time he is born to the time he dies—should do the three things that are artificially separated in our universities. He must learn to do his share of the useful routine work of the world, he should aim to improve the methods of doing this work and he should have some acquaintance with the work of others.

The prolongation of infancy marks off the higher animals from the lower, and men from all others. If the sensori-motor arcs are

closed at birth or soon thereafter, the creature can learn but little. So long as the brain is kept plastic, permitting the formation of new associations, there is room for intellectual progress. We have thus a psychological justification for the artificial extension of babyhood, but possibly the college senior at the age of twenty-three has been kept too long in this condition. Certain sensori-motor arcs should be early closed and certain associations definitely formed, or we shall never have the expert; but certain other paths must be kept open or the result will be a machine.

We begin as a matter of fact by teaching the child, supposing it to have escaped the snares of the kindergarten, certain strictly utilitarian studies—the three R's. Under a poorly paid and partially educated woman, we place a flock of children. They sit silent and cramped when movement is essential, not only for bodily health but also for the formation of ideas; they are crowded into an unhealthful room when all out-of-doors surrounds it; the individual child is as far as possible reduced to the average child; in six or eight hours a day for six or eight years the child laboriously acquires certain technical knowledge, the surviving part of which could probably be got in two hours a day during two years. Then in the high school, the youth perhaps takes up Latin, Greek, French and German, while decent English remains a foreign language; text-books in mathematics are arranged for the suppression of thought, and if science is taught it is made as remote as possible from human experience. At the age of eighteen or nineteen the boy has put on the quantity of cerebral fat which, when duly measured by the college entrance examination board for the Middle States and Maryland or some other automatic weighing machine, admits him to college. Here his physical and social environment is suddenly changed, but he finds himself pursuing the secondary studies of the preparatory school—more Latin, Greek, elementary mathematics and English composition—usually under immature tutors. Later in his course, he is allowed to elect miscellaneously, and his daily program may have some resemblance to that of a vaudeville performance. Then finally at the age of twenty-two or three those who stick to the educational system enter the professional schools and go to work in earnest, with no time for culture or research; while a few students prepare to be teachers and are encouraged to undertake independent investigation under the faculty of philosophy.

Mere criticism is nihilistic, and no sensible person would wish to alter suddenly an educational system that has slowly grown. The fact of its existence is evidence that it is the best we can do, but by no means proof that it is the best we shall do. I have no idea what a century will bring, but it is reasonable to assume that there are certain things that it will take. Ten years of age is early enough to begin

to read, write and calculate; primary education should be chiefly for the formation of motor habits; a child's head will not hold more miscellaneous facts than can be injected in a year or two; he can learn nearly as much of his present scholastic studies in two hours a day as in eight. If the required school attendance for each child were reduced to one half or one third, then without additional expense the fewer buildings and smaller equipment might be doubled or tripled in value, and the salaries of teachers might be doubled or tripled. The best trained teachers, more men than women, should be in charge of the younger children. If society must develop a class similar to the neuter insects, it should not have charge of the education of children. The boy should stay in the high school until he is eighteen and then go to the university, or he should enter the college at sixteen and pass forward to the university in two years. The man should begin to take part in the real work of the world at twenty-one, but he should never regard his education as complete, and should for many years, if not always, continue to spend some time in work at the university.

I believe in the practice system from start to finish. Let the child learn the best that the home can teach, let the younger child learn from the older, let the novice learn by helping the master. Each child should have as wide interests and as generous sympathies as may be; he should learn to do some useful work; he should strive to become an originator and a leader. Never in our educational system should these three chief ends of education be separated, least of all in the university.

The word 'culture' has for me acquired an objectionable connotation—it calls up a picture of manure applied to turnips or of microbes growing fat by feeding on gelatine. Boys of twenty-one, chiefly interested in quasi-professional athletic competitions and social organizations, incidentally nibbling at the academic flowers and fruits from which the fences have been removed, supported by their parents at the cost of $1,000 a head, are a variety of prize animal that can not become universal. The elective system, in so far as it means that a Procrustean course of study shall not be imposed mechanically on all students, but that his work shall be selected by the boy with the advice of judicious councilors, is one of our great educational advances. But the boy should have some definite aim from the outset; he should usually prepare himself to follow the trade or profession of his father, always aiming to reach a higher plane, while at the same time he and his teachers should always be on the watch for any special aptitude or sign of genius. The boy's studies should be related to his life's work, and the relation should be evident to him. Then apart from his main interest, he should have one or two recreations or avocations, as a sport or game, some branch of science or one of the fine arts. Here too he should be an expert, only an amateur in so far as he is led by

love. The group system of the Johns Hopkins University seems to be the best plan hitherto devised for securing the advantages and avoiding the dangers of the elective system.

Even an undiscriminating use of the elective system appears to me better than the obsolescent required course in Latin, Greek and elementary mathematics. Latin was once as much of a professional study as electrical engineering is to-day. By a natural evolution it became part of the insignia of a leisured aristocracy, educated with priests and by them. The use of quotations in which the quantities were given in accord with the peculiar accent of the English universities was a mark of birth and breeding, as are to-day the scars on the face of a German student. Literature and art based themselves on the classical tradition; the intrinsic beauty of the Greek civilization and the part played by Rome in history added to its strength. Even the most iconoclastic must regret the bankruptcy of classical culture, but at the same time the most conservative must acknowledge that the idol is broken. We certainly still feel entitled to sneer at the millionaire who orders a painting of Jupiter and Io and complains that only one of the ten is supplied, and she without her clothes; whereas it is not regarded as a lack of culture when an eminent historian regards the Fissure of Rolando as a chasm in the Pyrenees. But Latin versification is becoming as obsolete and as little used to mark the fine gentleman as the carrying of a rapier. A classical education is essential for certain lines of research, and will always attract its full share of the keenest intellects; but it is no longer wise or possible for a boy to devote eight years of his life to the dead languages in order that he may be admitted to an artificial aristocracy. Latin will survive for a long time in the secondary school on the ground that its illogical constructions supply an intellectual gymnastic, or because its roots are useful in learning French, understanding law terms and naming new species; but its part in education is no longer leading or dignified. In the twilight of the classical tradition it is the once radiant elder sister that I regret:

> **Müszig kehrten zu dem Dichterlande**
> **Heim die Götter, unnütz einer Welt,**
> **Die, entwachsen ihrem Gängelbande**
> **Sich durch eignes Schweben hält.**

There should surely be in our system liberal education, as well as opportunity to learn a trade. I can not, however, believe that superficial knowledge of many subjects is culture, while a thorough knowledge of a few is not; that studies are liberal in direct proportion to their uselessness; or that certain studies are humanistic and others inhuman. Greek literature may be a 'Brodstudien' and dentistry may be followed as a liberal art. That education is liberal which enlarges the sym-

pathies and emphasizes our common interests, not that which forms an exclusive clique. On the whole the sciences in their application to human life seem more likely to form an adequate basis for a common culture than the dead languages. But intellectual training demands specialization, whereas the emotions are more nearly shared in equal measure by all. Civic life or art, if we but had a native art, seems to be a better basis for common culture than any special sort of knowledge.

In my opinion the university is or should be a group of professional schools, giving the best available preparation for each trade and profession. It is more feasible to give such training than to teach culture or research. These, like the building of character, are not the result of any particular kind of curriculum. Culture comes from daily and immediate association with the best that the world has; and this should be found at the university. The leader is born a leader; what the university can do is to give him an opportunity. The kind of research that may be taught to the second-rate man is not the highest ideal of the university. The presumption is that the new facts recorded by the student are unimportant; just because they are new and discovered by the student. But if by research we mean the discovery of new truth and the creation of new lines of activity, then research is indeed the highest function of the university. When we find the man who can advance knowledge and the applications of knowledge to human welfare, be he student or professor, him we should all serve and reverence. But we do a grievous wrong if we assume that this man is found, and should be found, only in the faculty of philosophy. I am glad that our great leader, President Eliot, in his address at the inauguration of President Remsen, emphasized particularly the forward movement made by the establishment of the Johns Hopkins Medical School. Not because it requires for entrance the equivalent of the bachelor's degree, but because we have there the best specialized training, united with the highest culture and the freest research, it will become and has become the model for our medical schools, and for our schools of law, theology and technology. So long as we must have degrees, let the A.B., the A.M., the M.D. or other professional degrees, and the Ph.D., each mean, according to its measure, culture, expert training and independent research.

The general public doubtless regards the university as simply a place for the teaching of students, and there may be some justification for this opinion in the actual state of affairs. But over the doorway of the building in which is my laboratory of psychology we have inscribed the words 'For the advancement of natural science.' Historically the university has been far more than a school for boys. In

medieval Italy, France and Germany, men of maturity, usually attracted by a great personality, came together for mutual stimulus. The colleges of Oxford and Cambridge were monasteries for learned men before they became boarding schools. It may be our part here in America to develop the true university: A place where each would gladly learn and gladly teach; open summer and winter, night and day; a center in each community for the conservation of the best traditions and for the origination of the newest ideas; closely in touch with every forward movement of civic and national life; a home from which will go out, and to which will return, our leaders in every department of human activity. Twenty-five years ago perhaps only an Eliot or a Gilman could have realized the future of the American Universisty, but to-day even the man in the street must have some vague notion of its possibilities. Our college presidents and professors are called upon for the most important and difficult public functions. When New York City needs its leading citizen it finds him in the presidential chair of Columbia University. When Mr. Cleveland retires from public life, he allies himself with a university. There is no other office so fit for a past president of the United States as the presidency of a university.

The university is those who teach and those who learn and the work they do. The progress of the university depends on bringing to it the best men and leading them to do the best work. Our president, Mr. Remsen, in his admirable inaugural address, told us that the chief function of the university president is to find the right man, and his chief difficulty the lack of enough such men to go round. He considered the question of how far an increased salary would add to the supply of good men. I quite agree with Mr. Remsen that a professor will do about the same kind of work whether his salary is $4,000 or $10,000. If anywhere, in the university it should be to each according to his needs, from each according to his ability. The professor who must live in a city or who has children to educate should be given the necessary income. He should have an adequate pension in old age or in case of disablement; the university should insure his life in a sufficient sum to provide an income for his wife and minor children. The professorial chair can be made attractive by freedom, responsibility and dignity, rather than by a large salary. Still it must be remembered that we live in a commercial age, and men are esteemed in accordance with their incomes. While it may not, or at all events should not, matter greatly to the professor, it may be well for the community that those who do the most for it should be paid on the same scale as those of equal ability in other professions. It may not be necessary to double the salaries of all university men, but it would probably be desirable to have certain prizes that would represent to the

crude imagination of the public the dignity of the office and would perhaps attract young men of ability. The average salaries of teachers are about the same as in the other professions, but there are no prizes corresponding to those in the other professions. A clergyman may become a bishop, a lawyer may become a judge, a physician may acquire a consulting practise; and they may earn incomes of from $10,000 to $100,000. A professor can only earn a larger salary and an apparent promotion by becoming president of his university; and this I regard as unfortunate. As Mr. Remsen told us that the professor would be pleased but not particularly improved by an increase in salary, I may perhaps be permitted to suggest that a president might be pained, but would not be seriously injured by a reduction of his salary to that of the professor. My preference in this matter would be for the professor to have a fixed salary—perhaps $3,000 to $6,000, according to the expense of living in the neighborhood, with $300 to $600 subsidy for each of his children between the ages of 10 and 21. Advances in salary dependent on the favor of the authorities appear to be undesirable. If salaries must vary from $3,000 to $5,000, a man should be appointed at such salary as may be necessary, but should thereafter receive automatic increases, say of $500 after each five years of service. Then there should be a few research chairs in each university, promotion to which would be a mark of distinction, and occupancy of which would dispense from all routine work and carry a salary equal to that of the presidency.

The man of parts is born, but he must be found and given an opportunity. Lincoln, Grant and Lee stand forth in history, owing to the events of history, and if they had not been born others would have been found. The chief difficulty in securing the right men for university chairs is the small field from which they must be drawn. When we have a hundred thousand men of university training teaching in the schools, there will be those deserving promotion. When we have more students doing research work at the universities, there will be more men of genius for the higher offices. The Rockefeller Institute for Medical Research, and especially the Carnegie Institution, by encouraging men to carry on research at the universities, will perform in more ways than one a service of immense value. We should without delay introduce the *Privatdocent* system of Germany. We should not exclude a man from the university because there is no vacant position, but should welcome to affiliation every one who will add to its strength.

Our universities have suffered from in and in breeding and the promotion of men by a kind of civil service routine. The president should maintain a detective office for the discovery of exceptional men. It is more important to find a good man than to fill a vacant position.

The German plan of calling the best man without regard to whether he will accept or decline is better than our secret process. The English plan of having an expert board of electors for each chair possesses certain advantages. Migration of instructors as well as of students is desirable. Much would be gained if instructors in different universities would exchange places for a year, and especially if men from the small colleges were called to spend a year as lecturers at the great universities. When a national university is established at Washington, it would be well for its faculty to consist in part of men from other institutions who should spend one year in five or seven at the central university.

It is difficult to find the right man; and it is particularly unfortunate when the wrong man has been selected. Academic rights and academic freedom are troublesome problems. It seems that an opportunistic policy must be followed rather than definite rules. A university can not be conducted as a factory; and even a factory does not entirely ignore the human element. It is better that an occasional man should be retained who is not quite up to the standard, rather than that all professors should feel that their chairs are insecure, subject to the automatic law of supply and demand, or to the possible caprice of an individual. Assistants and instructors should be appointed for limited terms of years, and better men should replace them if better men can be found. They should never be promoted simply because they are the men on the ground. A professor's appointment should be for life, unless he violates the conditions implied in the contract. In making such an appointment, the university should accept the responsibility, fully realizing that a man, however carefully observed, is subject to a large probable error. Even on the commercial side it pays to take the risks, for with permanent tenure, men will accept smaller salaries; but the chief gain is the moral advantage of securing the complete loyalty of the professor and setting him free to do his work. Less competent men should not, of course, be permitted to teach required courses, and the departments to which they belong should be strengthened. Permanent tenure of office carries with it as a corollary a pension system. Some men are old at sixty and others are young at seventy, but as it is difficult and rather invidious for any authority to decide to which class a man belongs, it is perhaps desirable to pension all professors at a fixed age, permitting them thereafter to offer elective courses or not as they prefer.

Academic freedom is a subject that has not lacked discussion during the past year. So long as universities are dependent for support on gifts from rich men or on appropriations made by a legislature, there is real danger that the teaching of economics, sociology and some departments of history and philosophy may suffer improper limitations.

But so far as I am aware this is a danger rather than a fact. It should also be remembered that the university professor has responsibilities as well as rights. He should realize that views radically opposed to the sentiment of the community are not proper subjects for undergraduate teaching or for exploitation in the newspapers. On the other hand, there should be of course no inquisition in regard to a professor's private beliefs; there should be as little interference as possible with his graduate teaching and none with the presentation of his work or theories to experts in his own field.

The university is its men and their work. But certain externals are necessary or at least usual—buildings and equipment, a president and trustees. One of the notable services of the Johns Hopkins was to show that a great university can be lodged in humble quarters. I almost regret the erection of more expensive buildings and the present removal and rebuilding of the university. Yet it is certainly for the interests of the community as a whole that the exterior presence of the university should represent its dignity and influence. As the loving devotion and art of the community were once lavished on its cathedral, so they should now go toward making the university stately and beautiful. The university, with its affiliated libraries, museums, hospitals, art galleries, theaters and parks, should be the chief pride of the community; and the money that is needed should come freely. We do not, however, want imitation parthenons and pantheons; architects should be found who can plan the buildings that are best adapted to their uses.

The best scientific work has usually been done with modest equipment and inexpensive apparatus—it depends chiefly on the man. But as science becomes more exact and complex, there is undoubtedly increasing need of large expenditures. A million dollars or ten million dollars should not be grudged, if this sum is needed for an astronomical observatory or for an experimental farm. The investment is sure on the average, and likely in each individual instance to pay large interest to the public by actual decrease in the cost of production or distribution. But in any case the community can afford to contribute for ideal ends an amount that is insignificant when compared with its total expenditures. Books required by the worker should always be at hand, but it does not seem necessary for each university to maintain a museum of a million volumes. We should have two or three such collections in the country, but it is more economical to move books or even men, than to store and care for books that are used but once in a century. Museums and art galleries can also be limited in size without serious loss. Each should maintain certain typical exhibits and have in addition some well developed special departments. In general it

would be in the interest of economy and efficiency if there were more division of labor and cooperation among our universities than has hitherto obtained. It is not necessary for every university to have a complete equipment in every department.

The main ends of the university are the same in all lands, but our American presidents and boards of trustees are indigenous products which can scarcely be regarded as essential. They are the natural outcome of the denominational college, and have developed in line with methods of business organization that have proved themselves highly efficient. Given a small and compact group of men who represent a certain policy, but whose chief duty it is to elect an absolute dictator, who in turn appoints minor dictators, and the result is an economical and powerful machine. In politics, in business and in education, this form of despotism has prevailed, and has on the whole justified itself by the results. But it appears to be only a passing phase in educational development.

The college president has enjoyed a rapid evolution in the course of a single generation. Thirty or forty years ago he was a clergyman, as a matter of course; later he was likely to be selected for business qualifications; now he is a member of the faculty who unites executive ability with high scholarship. We seem to have made a further advance at Columbia by the election of a president who is at the outset an educational expert. He alone does not begin as an amateur and can devote himself to his work while cultivating his scholarship. But the demands now made on the university president are so diverse and exorbitant that even when he gives up both teaching and research they can scarcely be met. He can not be *in loco parentis* for 5,000 students; select and control 400 officers; coordinate the conflicting demands of incommensurable schools and departments; arrange diverse curricula in accordance with changing needs; superintend buildings and grounds; manage an estate of $10,000,000 and secure the additional funds always needed; be a public orator and monthly contributor to magazines; attend bicentennials, sesquicentennials and semi-sesquicentennials; occupy positions of honor and trust whenever called upon by the community or nation, and all the rest. It has become necessary to delegate part of these duties to deans and other officers, and it seems probable that the office of president should be divided and filled by two men of different type: one an educational expert, in charge of the internal administration; the other a man of prominence and weight in the community, in charge of external affairs.

The president and trustees as they now exist have their chief justification in financial conditions. We know that the lack of money is the root of all evil. Our private educational corporations, dependent on the generosity of millionaires, are in a remarkable and almost

anomalous position. Yet it is evident that this unique phase of development has not only kept the university in advance of popular appreciation, but has also tended to maintain the stability of society. At a time when large fortunes and monopolistic corporations are needed for the material development of the country, the generous gifts of a few men of great wealth have done much to allay popular clamor. It seems likely, however, that in the end the people will control monopolies and the universities supported by the profits of monopolies. There is no more reason for depending on the generosity or caprice of millionaires for our universities than for our ships of war. It has always seemed to me a curious perversion that elementary education, chiefly useful to the individual, should be free and supported by the state, whereas higher education, chiefly for the benefit of the state, should be a charge to the student and depend on private charity. I believe that the state universities are more nearly in the line of evolution than the private corporations, but there is every reason to hope that the latter will remain sufficiently plastic to adapt themselves to conditions that are likely to prevail. Even at present I think it would be desirable for our boards of trustees to be gradually increased in size, until they become large corporations, consisting of those who are most actively interested in the work of the university.

However it may be to-day, it does not seem likely that the money question will be the most troublesome one of the future. The people of this country spend $200,000,000 annually for sugar. The same quantity of sugar a hundred years ago would have cost five times as much, $1,000,000,000; the reduction in cost has been due to the applications of science in chemistry, agriculture and transportation. The saving on the cost of sugar for a single country in a year or two would pay for all the higher education and scientific investigation from the establishment of the University of Salerno to the present day. This is a statement easily understood by every voter and legislator; when it is once grasped the question for our universities will not be how to get money, but how to spend it judiciously. I also believe that the people of this country are not only good business men, but are idealists beyond others, and that patriotism and civic pride will lead them to increase the wealth of their universities as rapidly as it can be wisely used.

With the passing of the money question, I look forward to the passing of the president and the board of trustees. Democracy, as I understand it, does not mean that we shall not have leaders, but that we shall follow leaders because we recognize them as such. Our absentee and quasi-hereditary boards of trustees, and our presidents, ranging from King Log to King Stork, have on the whole administered their trusts in accordance with common sense and the opinion of the well-informed.

In so far as they have done so, their dictatorial power has been both harmless and useless. The professor is, as a rule, a free man, even though he may be looked upon as a fetus shut up in an incubator. The type of professor, who is exclusively concerned with settling 'the doctrine of the enclitic *De*,' or with distinguishing one beetle from another, survives on the stage and in novels, rather than at the university. In the scientific departments, at least, executive ability of a high order is needed for the conduct of a laboratory or the prosecution of research; and the demand is fully met. The university could not continually supply presidents and administrators of all kinds were there not a large supply of material. It has been said that university faculties are poor legislative bodies; if true, this would not be surprising, so long as their deliberations are confined to discussing questions such as whether they shall wear gowns at commencement, the decision being with the trustees. I believe that the university community is competent to direct the policy and administration of the university and will soon do so.

In these remarks I have used the freedom of speech that a teacher may claim; but it has certainly not been my intention to run amuck through our educational system. The man of science is by profession an optimist. None can write the equation giving the world's trajectory, but I believe that we are moving along an ascending curve. Never before has the average intelligence been so high, never before has a civilization been so securely established. Nor, I trust, are great men lacking. They say that we are failing in art and in literature; but those who are at the foot of a rainbow can see only the fog. In science and in other great departments of human activity progress is at a geometrical ratio. I also believe in the present and in the future of this democracy. Not only is the average well-being of the individual higher than elsewhere or hitherto, but we are contributing and shall increasingly contribute to political, business and educational organization; we are contributing and shall increasingly contribute to science, to scholarship and to art. The knowledge and the culture of the world have been freely given to us; it is our part to return them with usury. While in the energy of our pride we lord it over land and sea, we shall discover the truth, the beauty and the righteousness that lie hidden everywhere:

> In this broad earth of ours,
> Amid the measureless grossness and the slag,
> Enclosed and safe within its central heart,
> Nestles the seed perfection.

SCIENTIFIC LITERATURE.

BOTANY.

A NOTABLE book on modern botany has been prepared by Professor Campbell under the title of 'A University Text-book of Botany' (Macmillan) which fairly outlines the essentials of the science as understood to-day. Unlike many text-books it is a well-balanced presentation of the whole subject, and not a setting forth of some transient fad which the author may have taken up recently. Professor Campbell has succeeded in giving in the compass of a book of moderate size a good view of modern botany. His is not a radical view, but rather a conservative one, and his book indicates a distinct tendency away from the extreme position assumed by some American botanists in recent years. Instead of page after page of fine 'half tone' pictures of landscapes showing plants under all kinds of conditions, we have here a solid treatise in which the various parts of the subject are taken up in the order which has commended itself to the author as a teacher of many years' experience. After an introductory chapter, the author follows the usual sequence, viz., general morphology, cytology and histology, and then the special morphology, cytology and histology of the principal groups of plants, beginning with the lowest and passing from these by successive steps to the highest. This is the principal part of the book, occupying as it does fully four fifths of the pages. After this come several chapters on physiology, relation to environment, and geological and geographical distribution. Modern botany, as interpreted by Professor Campbell, is largely and quite emphatically structural. Physiology and ecology are distinctly subordinated to structure, as indeed they must be in any scheme of scientific instruction. Here as in mechanics, it is essential that the mechanism be clearly understood before the working of the machine can be critically studied. It will not do to study mechanism alone; there must be a study of the activities as well. We must see the machine in operation, but merely to 'see the wheels go round' gives little accurate knowledge, however diverting it may be to the participants in the entertainment. Modern botany is not a diversion; it is a science, and must be seriously studied. It requires hard work, and it is not wise to attempt to eliminate the serious parts, leaving only the easy and entertaining portions. The training in botany is and always should be as severe as that required of students doing work in other sciences.

THE PROGRESS OF SCIENCE.

LORD KELVIN IN AMERICA.

THE ways of a democracy must appear past finding out to those who observe us from a distance. When Prince Henry visited the United States the newspapers devoted half their space to the event; yet it might be supposed that Emperor William, the energetic, would come to America, if he wished to extend to us the social etiquette of foreign nations, and that we should regard with slight interest a lesser royal guest. When the greatest living Anglo-Saxon man of science visits us, the event passes unnoticed by the general public; yet Lord Kelvin's contributions to the applications of electricity, and especially his connection with the trans-Atlantic cable, might be expected to attract general attention.

Lord Kelvin has, of course, been cordially welcomed by his scientific colleagues. He accepted an invitation extended by wireless telegraphy to attend the installation of President Butler at Columbia University, and on April 21 he was entertained at the University by the national societies concerned with the physical sciences. Professor F. B. Crocker presided, and addresses of welcome were made by President Butler; by Professor Elihu Thomson, representing the American Institution of Electrical Engineers; by Professor A. G. Webster, representing the American Physical Society, and by Professor R. S. Woodward, representing the American Association for the Advancement of Science and other scientific societies. Lord Kelvin in his reply referred to his previous visits to America. He first landed on this continent in 1866 in Newfoundland when the work of Mr. Field in connection with the trans-Atlantic cable was of special importance; ten years later he came to the Centennial Exposition, where he saw the telephone invented by Mr. Bell; in 1884 he found the electric light of Mr. Edison; in 1897 he saw the electrical industries of Niagara Falls. Lord and Lady Kelvin were very cordially greeted and applauded by the 2,500 people present. In addition to the reception at Columbia University, Lord Kelvin was entertained at Cornell University, at the University of Rochester—the main object of his visit was to attend a meeting of the Kodak Company at Rochester—and at Yale University, where the degree of Doctor of Laws was conferred on him. In conferring this degree, President Hadley said: "You have joined the different regions of the earth by your investigations of the submarine telegraph; you have joined the different realms of human thought by your contributions to physical theory."*

THE NATIONAL ACADEMY OF SCIENCES.

THE spring meeting of the National Academy of Sciences did not differ in any unusual respect from other annual stated meetings. The Academy has three main objects—it is the official adviser of the government in scientific matters; it holds scientific sessions for the presentation of papers, and it has certain functions in recognizing scientific eminence and in bringing scientific men together. The first of these objects has become relatively unimpor-

* The portrait of Lord Kelvin given as a frontispiece is from an etching made for *Minerva* by Professor Hubert Herkomer.

tant since the government employs scientific experts in all departments, and is likely to apply to them rather than to the Academy for advice. The second function has also become less essential than formerly, owing to the development of special societies for each of the sciences. The third object has consequently become perhaps the most important. The annual elections are a recognition of scientific merit, and it is well that our leading scientific men should have the opportunity of meeting together to become acquainted with each other and with the work being carried on in different sciences and in different parts of the country. The program at Washington was of considerable interest. Mr. Alexander Agassiz, who was last year elected president of the Academy, reported on his recent expedition to the coral reefs of the Maldive Islands, and the evidence presented, in addition to that which he had already collected, seems definitely to negative Darwin's theory of the origin of coral reefs. This theory, it will be remembered, explains the atolls as due to the gradual subsidence of the floor of the ocean, the insects building the reefs as the floor sank. Mr. Agassiz has discovered a great number of facts which seem to be entirely incompatible with this theory. As is usual at the meetings of the Academy, astronomy was well represented. Dr. Seth C. Chandler offered a paper on the constant of aberration, which, however, was only read by title. Professor E. C. Pickering presented facts regarding the relations of the planet Eros to the solar parallax and its variations in brightness. Professor Asaph Hall described the disintegration of comets. Papers on chemistry and physics were presented by Professor Theodore W. Richards dealing with the atomic weight of cæsium and the significance of changing atomic volume; by Professor James M. Crafts on catalysis; by Professor E. W. Morley on the weight of the vapor of mercury, and by Professor E. L. Nichols on the optical properties of asphalt. Paleontological papers were presented by Professor H. F. Osborn and Professor A. S. Packard; psychological papers by Mr. C. S. Peirce and Professor J. McKeen Cattell, and an illustrated account of the physiological station on Monte Rosa by Professor H. P. Bowditch was given by Professor C. S. Minot. Mr. William Sellers read a paper adverse to the compulsory introduction of the metric system. Biographical memoirs of William A. Rogers, J. G. Barnard, Francis A. Walker and J. S. Newberry were presented, respectively, by Professor E. W. Morley, General Henry L. Abbot, Dr. John S. Billings and Dr. C. A. White. The new members elected were: William W. Campbell, director of Lick Observatory, Mount Hamilton, California; George E. Hale, director of Yerkes Observatory, Williams Bay, Wisconsin; C. Hart Merriam, chief of the Division of Biological Survey, U. S. Department of Agriculture, Washington, D. C.; William Trelease, director of the Missouri Botanical Garden, St. Louis; Charles R. Van Hise, professor of geology, University of Wisconsin, Madison.

THE METRIC SYSTEM IN THE UNITED STATES.

A BILL is now before Congress adopting the metric system of weights and measures as the standard in the United States. Though it does not seem likely that the bill will be passed during the present session it has been recommended by the committee on coinage, weights and measures, and the chances of its adoption seem more favorable than ever before. The bill requires the departments of the government to use the metric system after the beginning of the year 1904 and makes it the legal standard in the United States after January 1, 1907. The house committee has given a num-

ber of hearings on the subject, published in a pamphlet of 240 pages, and has drawn up a careful report. This report covers familiar ground, but in an unusually clear and straightforward manner. The attitude of Washington, Jefferson and Adams is referred to, and the history of the metric system of weights and measures is briefly reviewed. It is pointed out that the adoption of a decimal system of coinage in the United States was one of the strongest influences leading to the adoption of the metric system by France, and that Great Britain and the United States are practically the only non-metric countries. The weights and measures of Great Britain and the United States are not identical as is generally supposed, and there is no chance whatever that either system will become a universal system. The metric system has become necessary for scientific work; it would decrease the cost and labor of education; it would give unity to our manufactures, and is almost necessary for the extension of our commerce. The admitted expense and trouble involved in the adoption of the system are less, as has been shown in other countries, than is feared, and in any case the longer the adoption is delayed the greater will be the difficulty. The scientific, manufacturing and commercial interests of the country are under great obligations to Mr. John F. Shafroth, who, as chairman of the house committee on coinage, weights and measures, has devoted much careful attention to the subject.

THE CAUSES OF VOLCANIC ERUPTIONS.

THE recent volcanic outbreaks in the Lesser Antilles have naturally aroused much popular and scientific interest in these geological phenomena and have made a brief statement of current and accepted explanations of them a matter of interest. All these manifestations of heat are derived from the great stores which exist in the interior of the earth. The consideration of them and of the known increase of temperature with depth led earlier geologists to believe that the earth possessed a heated molten core and a cold and relatively thin exterior shell. But as further investigation developed correct conceptions of the rigidity of the globe in resisting strains produced by its rotation and the attraction of other heavenly bodies for its mass; and as the elevating effect upon the fusing points of rocks of an increase of pressure was realized, it was seen that the earth is practically solid clear through and that local reservoirs of molten rock beneath volcanic districts are alone admissible. That local reservoirs exist seems quite well established, and that the rock is sufficiently fluid to enable complex parent magmas to break up into various differential products is the latest result of the investigation of eruptive areas. Volcanoes are moreover arranged along great lines of geological disturbance and fracture as shown in the accompanying illustration. The fractures are naturally the conduits through which the great tension of the internal molten masses is eased by eruptions. The immediate propulsive force which drives the lava to the surface is the next topic of importance which challenges attention. Some geologists believe that the contraction of the globe and the sinking of one side of the great fractures above referred to force out the lava as juice might be squeezed through a rent in an orange. Others, however, attribute the propulsion to the vapors which are held dissolved or occluded in the lava and which are so much in evidence at times of eruption. The frightful explosions and the vast exhibitions of power which they present give much force to this conception. Imagine then a rising tide of lava. As it forces its way through the conduit it spreads earthquake shocks abroad. Reaching the surface its dissolved vapors explode with greater and greater violence and scatter tuffs and breccias over the neighboring country. They may rend

MAP OF VOLCANIC DISTURBANCES. (From Bonney's 'Volcanoes,' Putnam's Science Series.)

||||| Signifies Extinct Volcanoes.
+ Signifies Active Volcanoes, but is not intended to indicate either the number or the exact position.
- - - - - - Signifies the probable direction of lines of weakness in the earth's crust.

the crater and set loose floods of lava. As the energy expends itself, the violence declines and disappears. The volcano then yields only hot springs and gaseous emissions called fumaroles, until it is stone-cold.

SOME FACTS AND FIGURES CONCERNING THE EARTH.

THE earth is easily the most interesting and the best known to us of the bodies of the universe which have been subjected to scientific investigation. Not only do we know more of the earth than of any other member of the solar system, but we know more of the earth than of any of the smaller bodies which have been studied minutely in laboratories. It is true, of course, that a few bodies, like standards of length and mass, have been determined with great precision with respect to one or two of their properties; but our knowledge of the earth includes many of its properties, and some of them are known with a precision only surpassed by that of the standards referred to.

The surface of the earth is closely that of an oblate spheroid whose axes are known within about the hundred thousandth part, a precision near the limit possible in laboratory measurements of such bodies as inch ball-bearing spheres now made with wonderful exactness for commercial purposes. The surface and volume of this spheroid are found to be in round numbers two hundred million square miles and two hundred and sixty thousand million cubic miles respectively; and these numbers are known with an accuracy far surpassing that of the measured areas, for example, of the most valuable city properties, which are relieved of the necessity for precise measurement by the legal phrase, 'be the contents of the same more or less.' The magnitude of the work which has led to these results may be appreciated to some extent if one considers seriously how one would measure an area of two hundred million square miles with an error not greater, say than one fifty-thousandth part.

Less definite but of a higher order of magnitude are the figures expressing the quantity of mass of the earth, or what is sometimes designated by the scientifically meaningless phrase 'the weight of the earth.' We all have a tolerably clear idea of the mass in a ton of coal, but few of us are fitted to realize the nearly equally definite quantity of the earth's mass, which is in round numbers six thousand six hundred million million million tons. Of this total mass, the atmosphere, whose lenticular-shaped envelope includes a volume about one hundred and fifty times that of the solid part of the earth, contributes somewhat more than one millionth part, a small fraction of the whole, but yet millions of millions of tons in amount.

The regularity of rotation of the earth, or its constancy as a time-keeper, is no less surprising when expressed in numbers. The variation from day to day in the time of rotation is probably less than the hundredth of a second, or no greater, say, than the ten-millionth part of a day. Our best clocks and chronometers, and they are marvels of mechanical perfection, fall far short of this degree of constancy. Equally remarkable for stately regularity are the precession and nutation of the earth, by reason of which its axis of rotation describes a slightly fluted cone in the heavens, making one complete revolution in the leisurely interval of about twenty-six thousand years and thus rendering it essential for us to change pole stars from time to time. And still more noteworthy are the lately discovered minute wabblings of the earth with respect to its axis of rotation, whereby the latitude of a place varies from month to month, running through a lesser cycle in about fourteen months and through a greater cycle in some-

thing like seven years. That these recondite phenomena have been disentangled and reduced to precise numerical statement is at once conclusive evidence of method in the madness of terrestrial motions and of exquisite refinement in astronomical science.

The much discussed question of the age of the earth may now be said to have risen from the level of figures of speech to the higher plane of numerical expression. We are not able, and we may never be able, to assign the age of the earth in years, or in thousands of years as our most respected teachers have done in the recent past; but we may say without fear of anything worse than literary contradiction that the age of the earth must be reckoned in millions of years. Probably some hundreds of millions of years have elapsed since the earth became habitable to organic forms. Nature has plenty of time for her operations; and old as the earth must be in comparison with the centuries of human affairs, it is still active with the energy manifested in the earliest geological times. The processes of erosion and sedimentation, and that of secular contraction from loss of internal heat, are still asserting themselves occasionally (frequently, if a million years be used as the time unit) by such appalling outbursts as that which has just overwhelmed St. Pierre. And these processes, though fraught with calamities here and there to our race, must go on for millions of years yet to come.

BIOGRAPHIES OF EMINENT CHEMISTS.

WITHIN the last few years several particularly attractive biographies of distinguished chemists have been issued as volumes of the 'Century Science Series,' edited by Sir Henry E. Roscoe; they differ from other works in the same line in that they portray the men and their careers more graphically and concisely, and embody at the same time the results of the latest researches. One of these, written by Roscoe himself, bears the title 'John Dalton and the rise of Modern Chemistry' (New York, 1895).

Half a dozen memoirs of the Founder of the Atomic Theory had previously appeared, the most noteworthy being those by W. C. Henry (1854), by R. Angus Smith (1856), and by H. Lonsdale (1874). The first named forms one of the volumes printed for the Cavendish Society, the second includes a History of the Atomic Theory from the days of the Greeks to the time of Dalton, and is embellished with the most satisfactory of the printed portraits.

Roscoe's charming work is enlivened with facsimiles, extracts from letters, papers and books by Dalton, reminiscences by contemporaries, appreciations by later chemists and amusing anecdotes, the whole so simply and yet so vigorously written as to make a delightful narrative. There has always been much speculation as to the mental processes which led Dalton to conceive of the great theory indissolubly connected with his name, and this problem has only been quite recently solved by the discovery in the rooms of the Literary and Philosophical Society of Manchester (where the whole of the experimental work was carried on by Dalton) of his laboratory and lecture notebooks, in a number of volumes. It has been supposed that it was the experimental discovery of the law of combination in multiple proportions that led Dalton to the idea that chemical combination consists in the approximation of atoms of definite and characteristic weight, the atomic theory being thus adopted to explain the facts ascertained by chemical analysis. But an examination of these newly discovered manuscript notes shows that he arrived at these ideas from purely physical considerations along the line of the Newtonian doctrine of the atomic constitution of matter; he conceived of chemical combination as taking place

between varying numbers of atoms of definite weight, and then succeeded in confirming this view by the results of analyses made both by other chemists and by himself. This is precisely the inverse of the commonly accepted supposition.

This view of the genesis of Dalton's Atomic Theory has been published in a small volume with the title: 'A New View of the Dalton's Atomic Theory,' edited by Sir Henry E. Roscoe and Arthur Harden (London, 1896). The work contains also documents and letters by Dalton not previously published. No student of Dalton or of the atomic theory can afford to ignore this important contribution to history of chemistry.

Another volume in the Century Science Series deals with Sir Humphry Davy, poet and philosopher, and is by T. E. Thorpe (London, 1896). In preparing this Dr. Thorpe made use of the memoir on Davy by Dr. Paris (London, 1831), and that by Sir Humphry's brother, John Davy (London, 1858), as well as of contemporary periodicals, letters, and diaries of his friends and brother scientists. The first named of the earlier biographies has been found inaccurate as to matters of fact and extravagant in laudation; the second is written with candor and greater simplicity, and on the whole is more reliable. Dr. Thorpe's portrayal of the brilliant chemist is more correct and satisfactory; Davy's versatility is well brought out, his poetical writings, his philosophic studies, and his scientific labors, as well as his character as a man. Davy's discovery of the physiological effects of breathing 'laughing gas,' as it was called, made him conspicuous in the world of science when he was twenty-one years of age, and this prominence he maintained by his genius throughout life; at the age of thirty he isolated the metals of the alkalies, at the age of thirty-eight he invented the safety-lamp, at the early age of fifty-one he died.

One of Sir Humphry's most notable discoveries, certainly that which proved of the greatest benefit to mankind and to the progress of civilization (not excepting the safety-lamp), was Michael Faraday. The biography of this simple-minded and remarkable scientist, by Silvanus P. Thompson, forms another volume of the Century Science Series; two others deal with Justus von Liebig (by W. A. Shenstone) and with Pasteur (by Professor and Mrs. Percy Frankland), but the limited space at our command forbids further details.

Less brilliant, but no less patient an investigator was the Scotch chemist, Thomas Graham, whose career was very nearly conterminous with that of Liebig, and differed but little from that of Faraday. The Life and Works of Thomas Graham was prepared by Dr. Angus Smith, but owing to his feeble health (which terminated in death) the volume was edited by J. J. Coleman (Glasgow, 1884). Graham's life is rather inadequately depicted, but the book is enriched by more than sixty of his letters interspersed by brief notes of his contributions to science as well as by abstracts of all his published papers; among the latter may be mentioned those on the diffusion of gases and of liquids (1838–1863) and on the occlusion of hydrogen by metals (1868). In spite of his confining duties as Master of the Royal Mint, Graham found time for many other important investigations and for preparing a text-book which afterwards in connection with Friedrich Julius Otto became the celebrated and voluminous German 'Lehrbuch der Chemie' that passed through several editions.

The discovery of argon, and of other constituents of the atmosphere by Lord Rayleigh and William Ramsay in 1895 aroused renewed interest in the eccentric philosopher Cavendish, who narrowly escaped anticipating the recent discovery. The life of the Honorable Henry Cavendish, 'le plus riche de tous les savants et probablement aussi le plus savant de tous les riches,' was published by the Cavendish Society in

1851, being edited by Dr. George Wilson; Cavendish's electrical researches were edited by J. Clerk Maxwell from original manuscripts in the possession of the Duke of Devonshire, and published in 1879; since then there has been no important monograph concerning him.

THE ORIGIN OF THE HUMAN SPECIES.

THE discovery by Dubois of the much discussed remains of *Pithecanthropus erectus* in a situation which seems to indicate for them a late Pliocene horizon, has reawakened interest in the phylogeny and antiquity of man, and has led to a reexamination of some of the more interesting prehistoric remains. The Neanderthal skeleton has recently been carefully studied by Schwalbe and Klaatsch and minute comparisons have been made with recent races on the one hand, with the Spy remains and Pithecanthropus on the other and also with the recent anthropoids.

The results of these studies have demonstrated a great similarity between the Neanderthal and Spy skeletons and the possession by these of so many peculiarities which lie beyond the limits of variation in recent human races, that it has been thought necessary to recognize them as representatives of a distinct species of Homo, the *H. Neanderthaliensis*. Of this species we know at least three individuals and possibly more, and it seems certain that it is quite distinct from the *Pithecanthropus*, the skull characters of this Javanese form placing it on a much lower level than the Neanderthal-Spy skulls, and showing a more pronounced approach toward generalized anthropoid condition than is to be seen in the European skulls. There is, however, an enormous gap between even Pithecanthropus and the recent anthropoids, and, indeed, it seems certain that the latter cannot be regarded as coming into the direct line of human descent, but both these and existing human races must trace back to a common ancestor, whose characteristics are perhaps indicated in the cranial peculiarities of young anthropoids.

If this be the case it would seem that the origin of the human race must be referred back to a period antedating considerably the horizons to which *H. Neanderthaliensis* and *Pithecanthropus* belong. The former is assigned by Klaatsch to the first interglacial period, at the close of the Chelléan era, while the latter seems to pertain to the late Pliocene, and the divergence of form which led to the genus Homo would accordingly seem to be referable to the early Pliocene or possibly even to the Miocene period.

SCIENTIFIC ITEMS.

WE regret to record the death of Henry Morton, the eminent engineer, president of Stevens Institute of Technology since its foundation in 1870.—J. Sterling Morton, ex-Secretary of Agriculture, died on April 27.—The death is announced of Mr. Patrick T. Manson, son of Dr. Patrick Manson, on Christmas Island, whither he had gone to investigate the cause and treatment of beriberi, on behalf of the London School of Tropical Medicine.—M. Alfred Cornu, the eminent physicist, since 1867 professor at the Ecole polytechnique, Paris, has died at the age of sixty-one years.—M. Emile Renou, founder and director of the Meteorological Observatory at St. Mauri, died in Paris on April 7, aged eighty-seven.—M. Henri Filhol, professor of paleontology at the Jardin des Plantes, Paris, and the author of numerous important contributions to this science, has died at the age of sixty years.—Immanuel Lazarus Fuchs, since 1884 professor of mathematics in the University of Berlin, died on April 26 at the age of sixty-eight years.—Dr. E. von Pfleiderer, professor of philosophy at Tübingen, has died at the age of sixty years.

DR. ALEXANDER AGASSIZ has been appointed director of the Museum of Comparative Zoology, and Dr. A. E. Kennelly, of Philadelphia, has been appointed professor of electrical engineering at Harvard University.—The Hon. Carroll D. Wright, commissioner of labor, has been appointed president of the collegiate department of Clark University. It is understood that Mr. Wright will not, for the present at least, resign his position under the government or his work at Columbian or Catholic University.—The Secretary of War has sent to the House a recommendation that Surgeon-General Sternberg be granted the rank of major-general before his retirement on reaching the age limit June next.—The University of Edinburgh has conferred its LL.D. on Professor William James, the eminent psychologist of Harvard University, and on Dr. J. G. Schurman, president and formerly professor of philosophy at Cornell University.

DR. DANIEL COIT GILMAN, president of the Carnegie Institution, sailed for Europe on April 17, with a view to studying foreign scientific institutions.—Professor Solon I. Bailey, of the Harvard Astronomical Observatory, is about to leave for the observatory's branch at Arequipa, Peru, where he will especially study the planet Eros. Dr. W. H. R. Rivers, of Cambridge University, will shortly start on an expedition for the psychological study of the Todas of southern India on the lines of his work in Torres Straits.—Professors Victor C. Vaughan and Frederick G. Novy of the medical department of the University of Michigan will leave for Asia about the middle of June to investigate tropical dysentery.—Dr. J. L. Wortman, of the Peabody Museum of Yale University, will be in the West until September, exploring the fields in Dakota, Wyoming and the Bad Lands, where the late Professor Marsh made his important paleontological discoveries.—Ernst A. Bessey, in charge of the Section of Seed and Plant Introduction in the United States Department of Agriculture, has been detailed to proceed to Russia, the Caucasus, and Turkestan for the purpose of securing certain seeds of forage and cereal plants. He is to sail on July 2.—An expedition to northern Brazil will be sent out by the Austrian Government in the autumn under the direction of Dr. M. Steindachner, curator in the Vienna Museum of Natural History.

IN accordance with our plan of reprinting in each number of THE POPULAR SCIENCE MONTHLY an article which appears to be of special interest and which is inaccessible to most of our readers, we published last month part of a paper on the physiological effect of electrically charged molecules by Professor Jacques Loeb, of the University of Chicago, originally contributed to *The American Journal of Physiology*. The consent of the editor of the journal and of Professor Loeb was asked, but Professor Loeb wrote that he would prefer not to have the article republished, as owing to the misrepresentation that his work had suffered in the daily papers and in the magazines, he preferred to have his researches published only in technical journals. Unfortunately Professor Loeb's letter was not received until after the form had been printed, and we can only express our regret that the extracts were reprinted without his approval.